



ENGINEERING SUCCESS TOGETHER

## MEMORANDUM

Date: February 29, 2016 Job No.: 5000  
To: Tony DelGaizo, P.E. – Needham Town Engineer/Lou Taverna, P.E. – Newton City Engineer  
Cc:  
From: Jaklyn Centracchio, P.E., Justin Curewitz  
Subject: **Elliot Street/Central Avenue Bridge Detour – Traffic Impact Analysis**

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Per your request, BETA Group, Inc. (BETA) has performed a traffic analysis to study the impacts resulting from the full closure of the Elliot Street/Central Avenue Bridge for reconstruction. The purpose of this analysis was to evaluate a series of intersections that will be directly impacted by the bridge closure as well as the intersections that will have traffic detoured through them. The bridge closure is anticipated to be approximately six months. To minimize traffic impacts, the construction and closure of the bridge will overlap with the school vacation period.

### DETOUR ROUTES

Two separate detour routes, proposed by the City/Town, were visited to verify the functionality of them; one for use by cars only and another for a combination of cars and trucks. Due to the low clearance of several roadways that pass under Route 9 bridges, a truck detour was designed to route truck traffic away from these low bridge clearances. This was done using sign assemblies to direct traffic along the appropriate detour routes with both cars and trucks in mind. A sketch showing the proposed detour routes are provided in **Figure 1**.

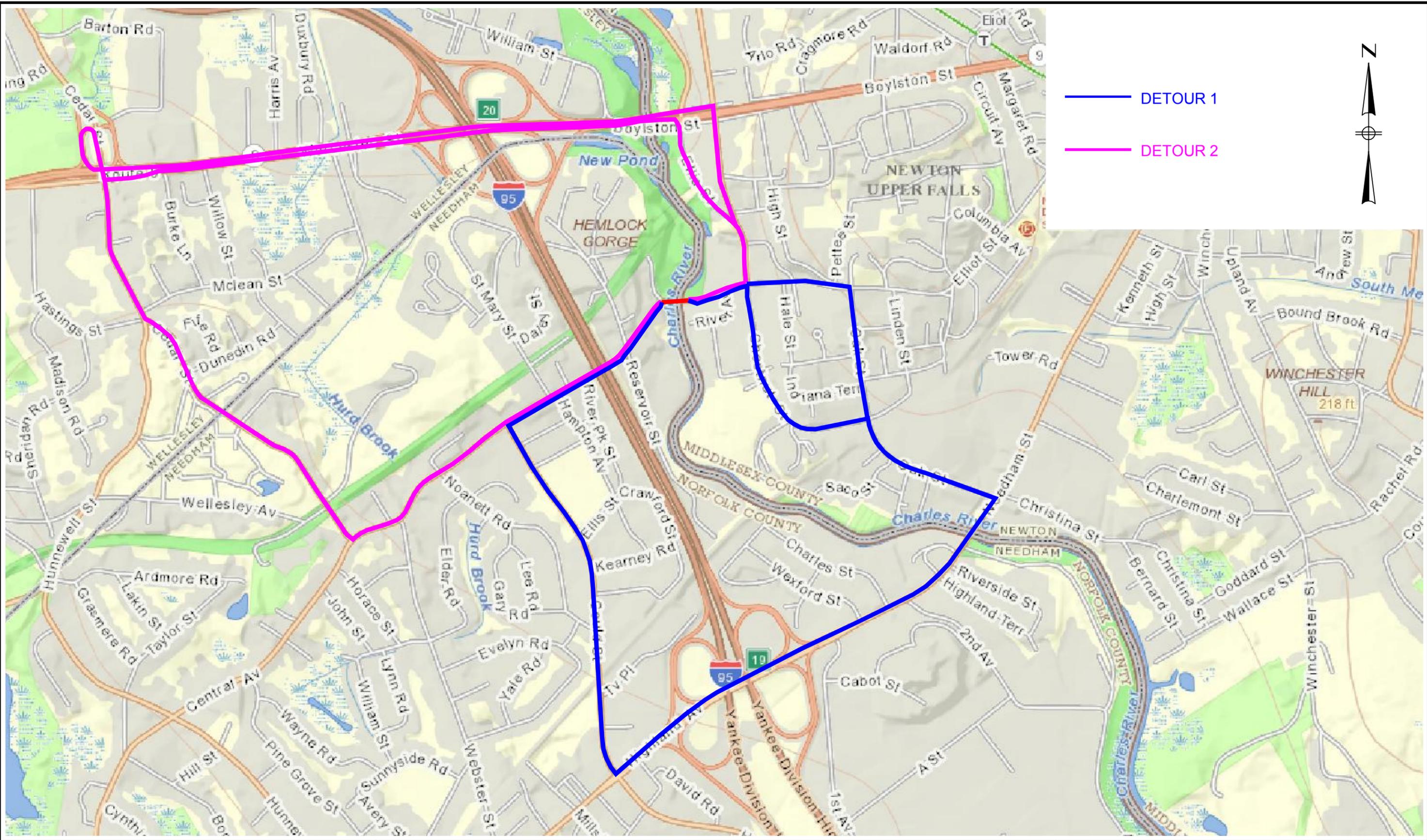
The two detour routes will divert traffic either to the north or to the south of the Elliot Street and Central Avenue. Detour 1 will be used for both cars and trucks, while Detour 2 will be for cars only. While cars are able to use either detour route, trucks must use the southern detour route, resulting in the following two different analysis scenarios which are discussed in detail in the Methodology Section.

#### Detour 1: Cars and Trucks

Elliot Street  
Oak Street  
Needham Street/Highland Avenue  
Gould Street  
Central Avenue

#### Detour 2: Cars only

Elliot Street  
Chestnut Street/Ellis Street  
Route 9  
Cedar Street  
Central Avenue



### Central Avenue/Elliot Street over Charles River

Needham/Newton, MA

### Figure 1

Proposed Detour Routes

## TRAFFIC VOLUMES

The Elliot Street Bridge provides a single travel lane in each direction, spanning the Charles River and connecting the Town of Needham and the City of Newton. In total, ten intersections were identified and analyzed; all of which will be impacted by the proposed detour routes. These ten intersections are:

- Chestnut Street at Elliot Street (Signalized)
- Chestnut Street at Oak Street (Signalized)
- Needham Street at Oak Street/Christina Street (Signalized)
- Highland Avenue at Gould Street/Hunting Road (Signalized)
- Elliot Street at High Street (Unsignalized)
- Elliot Street at Oak Street (Unsignalized)
- Central Avenue at Cedar Street (Unsignalized)
- Central Avenue at Webster Street (Unsignalized)
- Central Avenue at Gould Street (Unsignalized)
- Central Avenue at Reservoir Street (Unsignalized)

Manual Turning Movement Count (TMC) data were collected in October 2015 for all but one intersection. The intersection of Highland Avenue at Gould Street and Hunting Road was collected in June 2014 as presented in the Wingate Senior Living Impact Study. In addition, 48 hour Automatic Traffic Recorder (ATR) Counts were collected on either side of the bridge along Central Avenue and Elliot Street in October 2015. The network peak hours were found to be 8:00 to 9:00 AM and from 5:00 to 6:00 PM and are shown in **Figure 2**.

## DETOUR ANALYSIS SCENARIOS/TRIP DISTRIBUTION METHODOLOGY

To examine the expected impacts of detour operations during bridge closure, existing traffic were re-routed and assigned to one of the two detour routes, resulting in changes in turning movement volumes at the study intersections. The following scenarios were discussed during detour operations to account for the separation of truck traffic from car traffic.

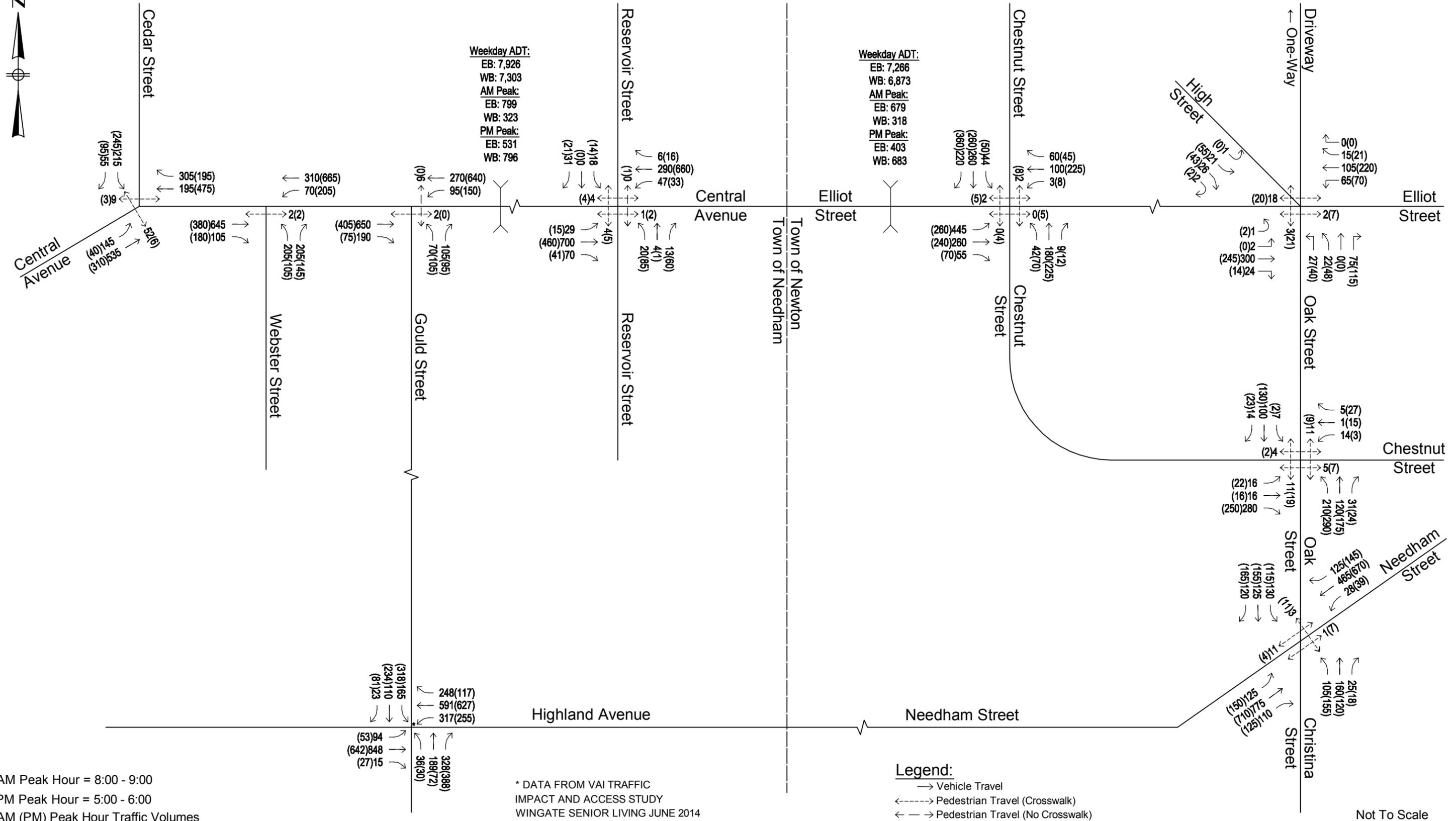
Scenario 1 (100% Detour):

- Assumes that all truck traffic follows the truck route while the remaining traffic would follow the car route in both directions of travel. This would result in all existing truck traffic currently using the bridge to use Detour 1, while all remaining traffic uses Detour 2

Scenario 2 (50% Detour):

- Still assumes that all truck traffic follows the truck route (Detour 1) while the remaining traffic would be split evenly between Detour 1 and Detour 2.

To evaluate the potential traffic impacts for these two scenarios, traffic volumes were diverted based upon the specific detour taken as well as their origin and destination. Several steps were taken to estimate these diverted trips and assign them to the network. First, the existing traffic using the bridge was obtained for eastbound and westbound traffic during the peak hours from the ATR counts east of the bridge and are summarized in **Table 1**.



AM Peak Hour = 8:00 - 9:00  
 PM Peak Hour = 5:00 - 6:00  
 AM (PM) Peak Hour Traffic Volumes

Not To Scale



**Central Avenue/Elliot Street over Charles River**  
 Needham/Newton, MA

**Figure 2**  
 Existing (2015) Peak Hour  
 Turning Movement Volumes

**Table 1 – Existing Bridge Traffic**

Direction	Volume	
	AM Peak Hour	PM Peak Hour
Eastbound	679	403
Westbound	318	683
Total	997	1086

Second, these volumes were traced back to the turning movements at each of the study intersections where they originated from in order to account for the reduction of trips in these movements when the detour is used. To complete this step, percentages based on turning movement counts were used to calculate the volumes and movements in which traffic crossing the bridge originated from. Once calculated, this traffic was then applied to the specific detour depending on the scenario. This was completed by assigning the number of trips that will use the detour to that specific intersection movement and subtracting them from the original movement to avoid double-counting the trip. For example, at the intersection of Elliot Street and Chestnut Street under Scenario 1 (100% Detour), the westbound through traffic will not be able to cross the bridge when closed and must use the northern detour route. This results in subtracting the total number of trips that would currently cross the bridge from the through movement and adding them to the right turn movement to utilize the northern detour route. The same process was extrapolated to all the study intersections in both scenarios. A summary of the total diverted trips under these two scenarios is shown in **Figure 3** and **Figure 4**.

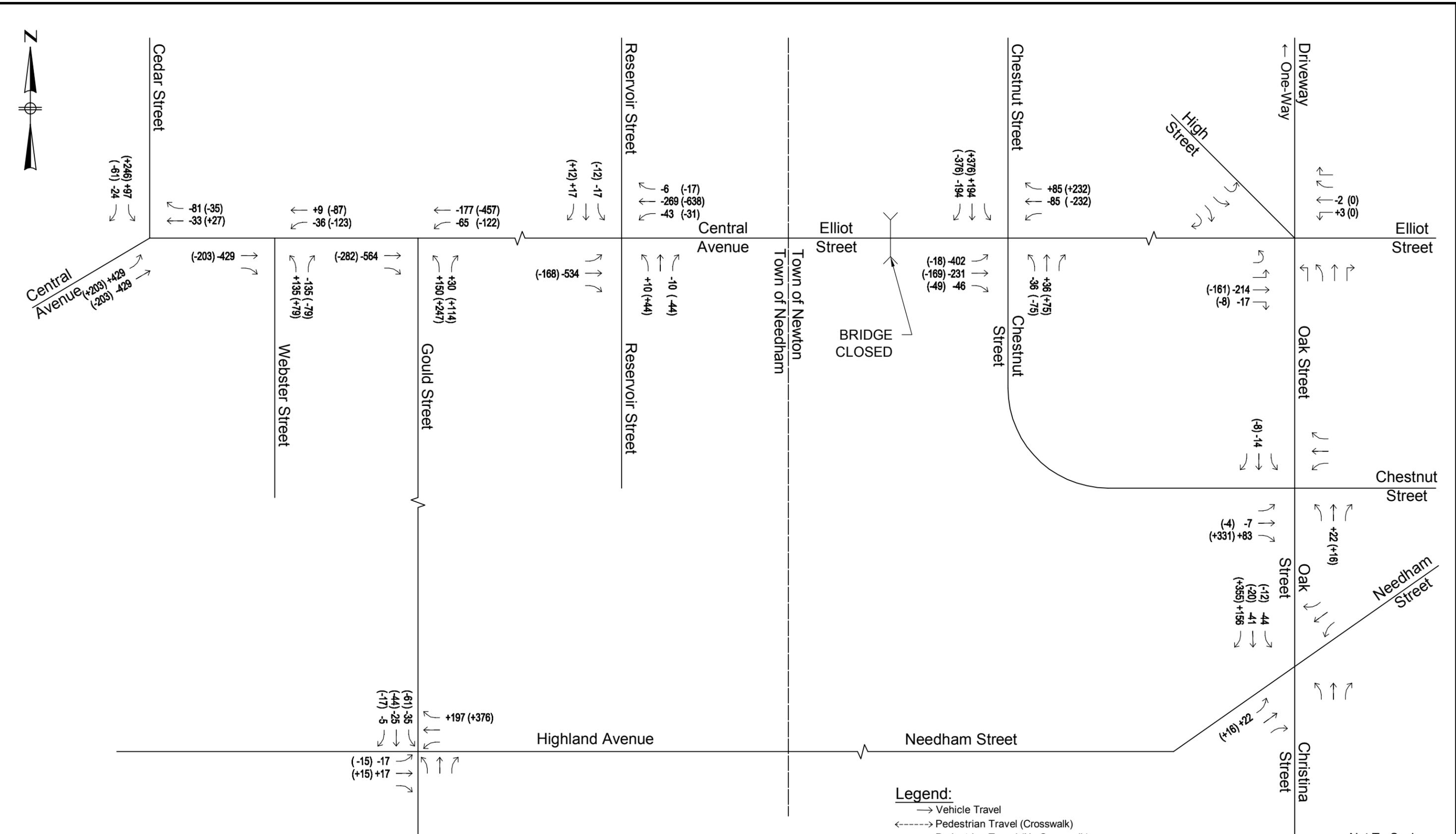
Once the total diverted trips were calculated, they were then applied to the existing volumes to represent the resultant turning movement volumes during each of the detour scenarios. **Figure 5** and **Figure 6** show the future turning movement volumes for the network during detour operations.

## CAPACITY ANALYSIS

### Existing Conditions

In order to evaluate existing traffic conditions, a capacity (level of service) analysis was performed. This analysis was performed using methods of the *2010 Highway Capacity Manual* published by the Transportation Research Board. For intersections, six levels of service (LOS), "A"- "F", have been established with "A" representing very good operation and "F" representing very poor operation. For signalized and unsignalized intersections, level of service is defined in terms of total delay and is computed for individual intersection turning movements. Delay is a measure of driver discomfort, frustration, fuel consumption, and lost travel time.

Level of service criteria for signalized and unsignalized intersections have been defined as shown in **Table 2** and **Table 3**.



AM (PM) Peak Hour Traffic Volumes

Not To Scale

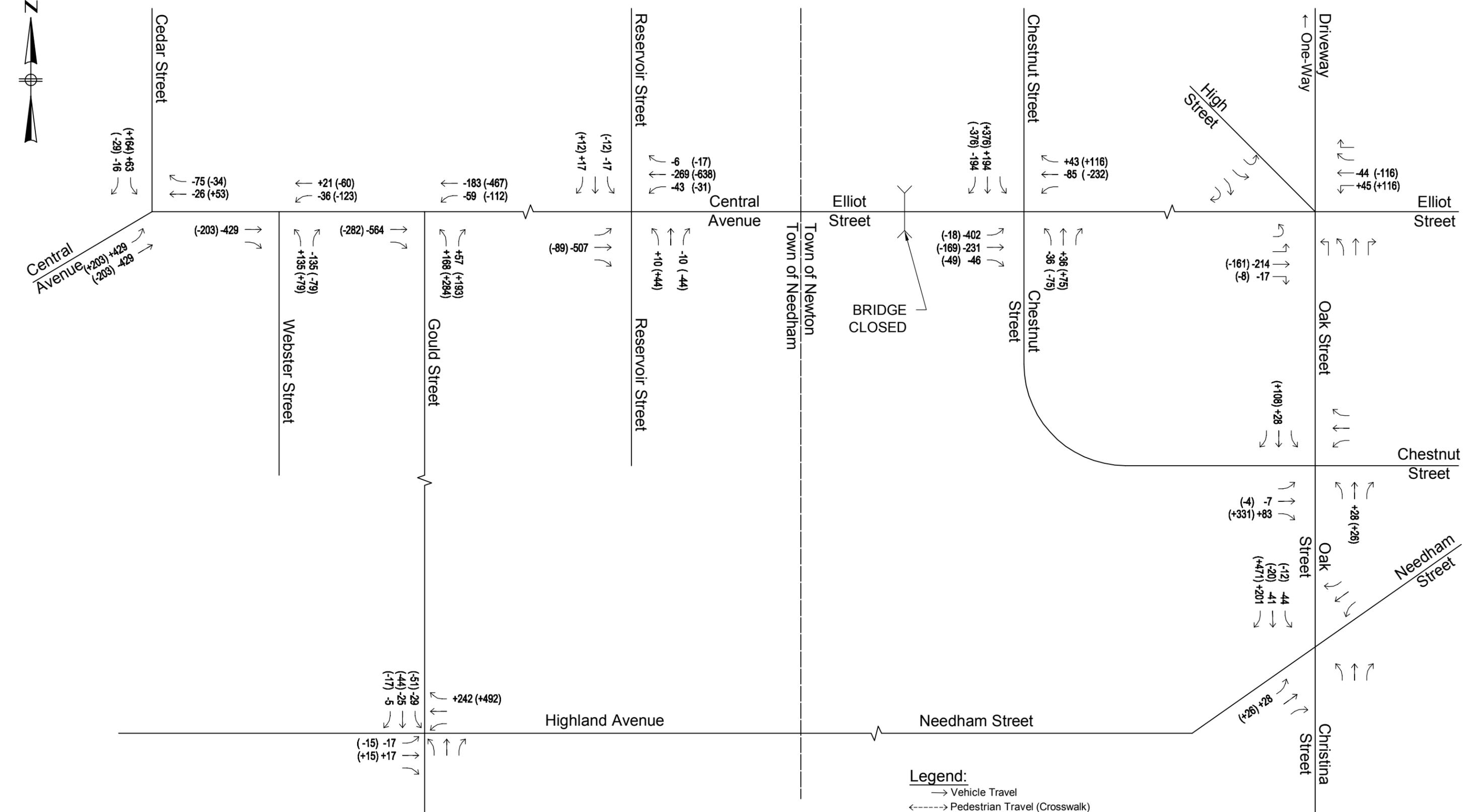


### Central Avenue/Elliot Street over Charles River

Needham/Newton, MA

### Figure 3

Scenario 1 -  
Diverted Trips (100% Detour)



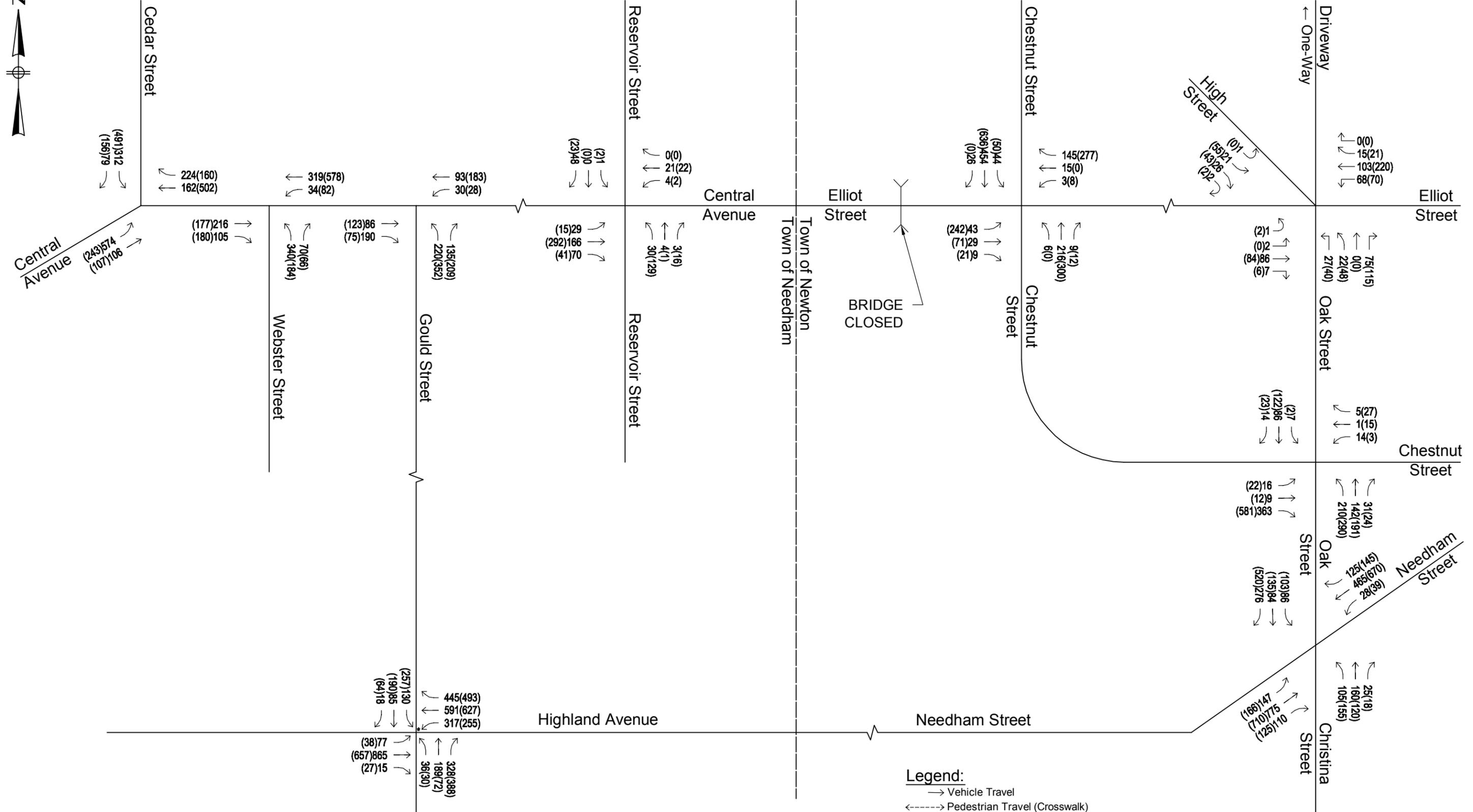
AM (PM) Peak Hour Traffic Volumes

Not To Scale



**Central Avenue/Elliot Street over Charles River**  
 Needham/Newton, MA

**Figure 4**  
 Scenario 2 -  
 Diverted Trips (50% Detour)



AM (PM) Peak Hour Traffic Volumes

Not To Scale

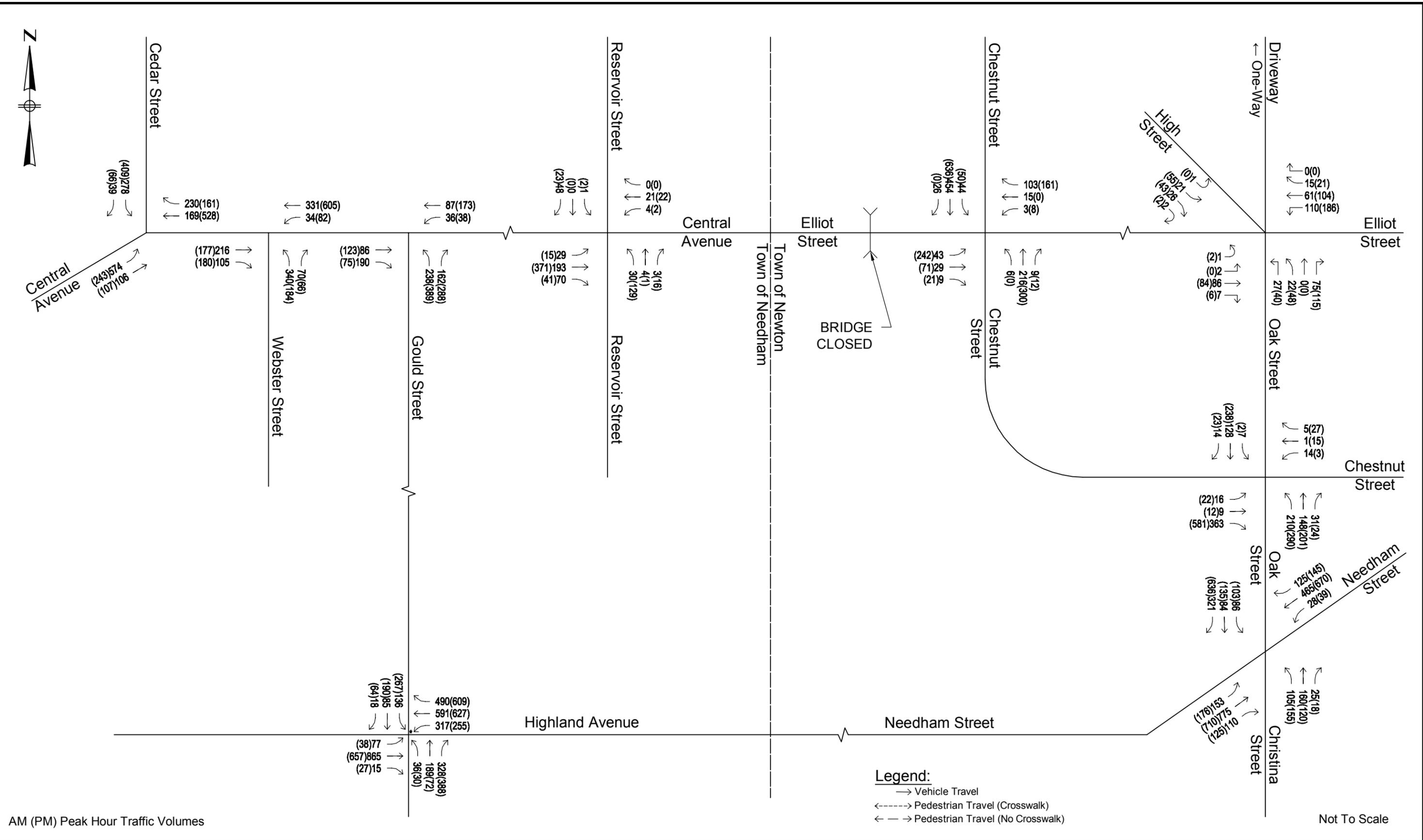


### Central Avenue/Elliot Street over Charles River

Needham/Newton, MA

### Figure 5

Future (2015) with Bridge Closure  
 Turning Movement Volumes Scenario 1 (100% Detour)



**Central Avenue/Elliot Street over Charles River**  
 Needham/Newton, MA

**Figure 6**  
 Future (2015) with Bridge Closure  
 Turning Movement Volumes Scenario 2 (50% Detour)

**Table 2 – Level of Service Criteria (Signalized Intersections)**

LOS	Control Delay (Sec/Veh)	General Description
A	≤ 10	Free flow
B	>10 and ≤ 20	Stable flow (slight delays)
C	>20 and ≤ 35	Stable flow (acceptable delays)
D	>35 and ≤ 55	Approaching unstable flow (tolerable delay)
E	>55 and ≤ 80	Unstable flow (intolerable delay)
F	>80	Forced flow (jammed)

**Table 3 – Level of Service Criteria (Unsignalized Intersections)**

LOS	Control Delay (Sec/Veh)	General Description
A	≤ 10	Free flow
B	>10 and ≤ 15	Stable flow (slight delays)
C	>15 and ≤ 25	Stable flow (acceptable delays)
D	>25 and ≤ 35	Approaching unstable flow (tolerable delay)
E	>35 and ≤ 50	Unstable flow (intolerable delay)
F	>50	Forced flow (jammed)

A level of service analysis was performed for the existing signalized and unsignalized intersections expected to be most impacted by detour operations using Synchro 8, Build 805. A summary of the results of the capacity analysis are shown in **Table 4** and **Table 5**.

**Table 4 – Level of Service Results - Existing (2015) – AM & PM Peak Hour (Signalized)**

INTERSECTION	AM Peak Hour					PM Peak Hour				
	LOS	Delay*	v/c	50th % Queue	95th % Queue	LOS	Delay*	v/c	50th % Queue	95th % Queue
<b>Chestnut Street at Elliot Street</b>										
Chestnut Street NB L/T/R	C	21.1	0.43	97'	224'	B	18.1	0.59	134'	306'
Chestnut Street SB L/T/R	D	38.2	0.87	281	#615	C	29.8	0.86	285	#750
Elliot Street EB L/T/R	F	286.8	1.55	650	#1157	F	**	2.15	650	#962
Elliot Street WB L/T/R	B	18.8	0.22	49	131	C	27.8	0.54	138	292
<b>Overall</b>	<b>F</b>	<b>143.2</b>				<b>F</b>	<b>201.8</b>			
<b>Chestnut Street at Oak Street</b>										
Chestnut Street NB L/T/R	B	12.3	0.62	55'	#344'	B	17.4	0.77	87'	#504'
Chestnut Street SB L/T/R	A	7.9	0.20	17	78	A	8.0	0.20	20	99
Oak Street EB L/T/R	C	22.4	0.32	8	85	C	22.5	0.32	10	86
Oak Street WB L/T/R	C	21.7	0.17	6	22	C	29.0	0.56	21	44
<b>Overall</b>	<b>B</b>	<b>15.3</b>				<b>B</b>	<b>18.0</b>			
<b>Needham Street at Oak Street/Christina Street</b>										
Needham Street NB L	A	7.5	0.35	24'	57'	B	16.5	0.65	31'	#128
Needham Street NB T/R	B	18.3	0.86	276	#512	B	15.3	0.81	257	426
Needham Street SB L	A	6.8	0.20	5	18	A	7.2	0.25	7	25
Needham Street SB T/R	A	9.3	0.59	130	213	B	14.0	0.78	233	386
Oak Street EB L/T	E	55.1	0.92	122	#267	D	39.2	0.84	128	#266
Oak Street EB R	B	18.7	0.08	0	38	B	19.2	0.11	0	44
Christina Street WB L/T/R	F	113.7	1.12	177	#328	F	248.6	1.44	208	#360
<b>Overall</b>	<b>C</b>	<b>32.1</b>				<b>D</b>	<b>45.2</b>			
<b>Highland Avenue at Gould Street/Hunting Road</b>										
Hunting Road NB L/T	E	64.9	0.82	188'	#416'	E	67.8	0.71	90'	#213
Hunting Road NB R	C	28.4	0.36	54	125	D	38.6	0.48	68	143
Gould Street SB L	E	69.1	0.79	131	251	D	46.5	0.72	235	#480
Gould Street SB T/R	E	62.6	0.73	128	247	E	56.7	0.84	290	#620
Highland Avenue EB L	E	74.1	0.74	76	#217	F	97.3	0.78	44	#153
Highland Avenue EB T/R	E	66.0	0.97	363	#714	D	52.5	0.83	275	#520
Highland Avenue WB L	E	72.1	0.90	249	#574	E	68.1	0.86	218	#405
Highland Avenue WB T/R	C	30.6	0.63	259	478	C	33.4	0.68	273	443
<b>Overall</b>	<b>D</b>	<b>52.7</b>				<b>D</b>	<b>48.1</b>			
* Delay is expressed in seconds per vehicle										
** Delay is greater than 300 seconds										
# - 95th percentile volume exceeds capacity, queue may be longer. Queue shown is maximum after 2 cycles.										

**Table 5 – Level of Service Results - Existing (2015) – AM & PM Peak Hour (Unsignalized)**

INTERSECTION	AM Peak Hour				PM Peak Hour			
	LOS	Delay*	v/c	95th % Queue	LOS	Delay*	v/c	95th % Queue
<b>Elliot Street at High Street</b>								
High Street SB L	B	13.6	0.17	15'	C	16.3	0.32	35'
Elliot Street EB L	A	0.0	0.00	0	A	0.0	0.00	0
<b>Elliot Street at Oak Street</b>								
Oak Street NB LTR	A	9.8	0.22	20'	B	11.2	0.34	38'
Elliot Street EB LTR	B	12.3	0.52	75	B	13.3	0.53	78
Elliot Street WB LTR	B	10.4	0.32	33	B	12.6	0.47	63
<b>Central Avenue at Cedar Street</b>								
Cedar Street SB L/R	F	**	2.76	783'	F	184.0	1.27	440'
Central Avenue EB L	A	9.9	0.18	15	A	9.3	0.05	3
<b>Central Avenue at Webster Street</b>								
Webster Street NB L/R	F	**	1.89	783'	F	**	1.82	503'
Central Avenue WB L	A	9.9	0.10	8	A	9.5	0.22	20
<b>Central Avenue at Gould Street</b>								
Gould Street NB L/R	F	113.8	1.03	243'	F	482.5	1.89	483'
Central Avenue WB L	B	10.8	0.15	13	A	9.2	0.18	15
<b>Central Avenue at Reservoir Street</b>								
Reservoir Street NB L/T/R	E	35.8	0.28	28'	F	**	1.55	438'
Reservoir Street SB L/T/R	C	22.7	0.23	23	D	32.3	0.25	23
Central Avenue EB L	A	8.1	0.03	3	A	9.1	0.02	3
Central Avenue WB L	A	9.5	0.06	5	A	8.6	0.03	3
* Delay is expressed in seconds per vehicle								
** Delay is greater than 300 seconds								

As can be seen in the above tables, several deficiencies are seen during the Existing conditions and are highlighted for clarity. These deficiencies are highlighted for all intersections or individual movements that operate at LOS F or for any movements that have significantly long queues.

Detour Operations

To examine the expected impacts of detour operations during bridge closure, a level of service analysis was performed for the intersections that are expected to experience a change in turning movement volumes as a result of the detour routes. For each of the two detour scenarios, a level of service analysis was performed using the turning movement volumes in **Figure 5** and **Figure 6**. The criteria used for the analysis are the same as in the existing conditions. A summary of the analysis results is shown in **Table 6** and **Table 7** for the 100% Detour, while **Table 8** and **Table 9** show the analysis results for the 50% Detour.



**Table 6 – Level of Service Results – 100% Detour (2015) – AM & PM Peak Hour (Signalized)**

INTERSECTION	AM Peak Hour					PM Peak Hour				
	LOS	Delay*	v/c	50th % Queue	95th % Queue	LOS	Delay*	v/c	50th % Queue	95th % Queue
<b>Chestnut Street at Elliot Street</b>										
Chestnut Street NB L/T/R	A	6.6	0.25	27'	137'	B	14.9	0.39	109'	242'
Chestnut Street SB L/T/R	A	9.7	0.61	83	370	C	26.9	0.83	307	#773
Elliot Street EB L/T/R	C	24.5	0.44	20	88	F	297.2	1.55	331	#569
Elliot Street WB L/T/R	C	22.3	0.18	4	65	C	24.2	0.22	3	72
<b>Overall</b>	<b>B</b>	<b>12.1</b>				<b>F</b>	<b>84.6</b>			
<b>Chestnut Street at Oak Street</b>										
Chestnut Street NB L/T/R	B	13.1	0.65	62'	#385	C	22.2	0.82	104'	#615'
Chestnut Street SB L/T/R	A	8.1	0.18	15	73	A	9.2	0.20	21	114
Oak Street EB L/T/R	C	22.5	0.35	7	88	C	23.5	0.51	9	120
Oak Street WB L/T/R	C	21.6	0.17	6	22	C	20.2	0.12	8	20
<b>Overall</b>	<b>B</b>	<b>16.4</b>				<b>C</b>	<b>21.1</b>			
<b>Needham Street at Oak Street/Christina Street</b>										
Needham Street NB L	A	7.9	0.41	30'	69'	D	45.6	0.88	53'	#180'
Needham Street NB T/R	B	18.2	0.86	276	#512	B	13.6	0.78	229	376
Needham Street SB L	A	6.8	0.19	5	18	A	6.8	0.21	7	22
Needham Street SB T/R	A	9.2	0.59	130	213	B	14.2	0.79	233	386
Oak Street EB L/T	C	24.1	0.57	72	#142	C	29.6	0.72	109	#224
Oak Street EB R	B	19.5	0.19	0	56	D	50.3	0.93	158	#367
Christina Street WB L/T/R	D	41.8	0.86	137	#288	F	160.8	1.24	191	#344
<b>Overall</b>	<b>B</b>	<b>18.8</b>				<b>D</b>	<b>39.0</b>			
<b>Highland Avenue at Gould Street/Hunting Road</b>										
Hunting Road NB L/T	E	62.5	0.81	181'	#411	E	60.2	0.68	81'	#213'
Hunting Road NB R	C	27.2	0.35	51	122	C	34.6	0.42	44	119
Gould Street SB L	E	62.3	0.71	98	200	D	49.4	0.72	178	352
Gould Street SB T/R	E	58.1	0.65	95	194	E	60.7	0.85	217	#429
Highland Avenue EB L	E	63.5	0.64	60	#165	E	78.5	0.68	29	#108
Highland Avenue EB T/R	E	62.8	0.96	356	#722	D	42.7	0.75	248	#535
Highland Avenue WB L	E	66.4	0.88	240	#569	E	60.2	0.83	196	#405
Highland Avenue WB T/R	C	31.6	0.73	307	#618	D	37.0	0.87	387	#770
<b>Overall</b>	<b>D</b>	<b>48.8</b>				<b>D</b>	<b>44.2</b>			
* Delay is expressed in seconds per vehicle										
# - 95th percentile volume exceeds capacity, queue may be longer. Queue shown is maximum after 2 cycles.										

**Table 7 – Level of Service Results – 100% Detour (2015) – AM & PM Peak Hour (Unsignalized)**

INTERSECTION	AM Peak Hour				PM Peak Hour			
	LOS	Delay*	v/c	95th % Queue	LOS	Delay*	v/c	95th % Queue
<b>Elliot Street at High Street</b>								
High Street SB L	B	10.7	0.12	10'	B	12.1	0.23	23'
Elliot Street EB L	A	0.0	0.00	0	A	0.0	0.00	0
<b>Elliot Street at Oak Street</b>								
Oak Street NB LTR	A	8.9	0.20	18'	B	10.1	0.31	33'
Elliot Street EB LTR	A	8.5	0.20	18	A	9.5	0.27	28
Elliot Street WB LTR	A	9.7	0.30	30	B	11.5	0.44	55
<b>Central Avenue at Cedar Street</b>								
Cedar Street SB L/R	F	**	14.14	1515'	F	**	4.17	1745'
Central Avenue EB L	B	4.4	0.62	110	A	10.6	0.28	28
<b>Central Avenue at Webster Street</b>								
Webster Street NB L/R	F	101.8	1.09	380'	F	92.4	0.99	245'
Central Avenue WB L	A	8.1	0.03	3	A	8.2	0.07	5
<b>Central Avenue at Gould Street</b>								
Gould Street NB L/R	B	21.6	0.69	140'	C	92.7	1.11	518'
Central Avenue WB L	A	8.0	0.03	3	A	7.7	0.03	3
<b>Central Avenue at Reservoir Street</b>								
Reservoir Street NB L/T/R	B	11.7	0.08	5'	C	17.5	0.48	65'
Reservoir Street SB L/T/R	A	8.8	0.06	5	A	8.9	0.03	3
Central Avenue EB L	A	7.4	0.02	3	A	7.3	0.01	0
Central Avenue WB L	A	7.4	0.01	0	A	8.0	0.01	0
* Delay is expressed in seconds per vehicle								
** Delay is greater than 300 seconds								

As can be seen in the tables above, Scenario 1 (100% Detour) results in additional deficiencies than those seen in the Existing conditions and are summarized below:

**Chestnut Street at Oak Street**

- Overall intersection LOS degrades from LOS B to LOS C in the PM Peak Hour
- Chestnut Street northbound degrades from LOS B to LOS C in the PM Peak Hour

**Needham Street at Oak Street/Christina Street**

- Needham Street northbound left-turn degrades from LOS B to LOS D in the PM Peak Hour
- Oak Street eastbound right-turn degrades from LOS B to LOS D in the PM Peak Hour
- Oak Street eastbound right-turn 95<sup>th</sup> percentile queue increases from 44 feet to 367 feet in the PM Peak Hour

**Highland Avenue at Gould Street/Hunting Road**

- Highland Avenue westbound through/right lane degrades from LOS C to LOS D in the PM Peak Hour
- Highland Avenue westbound through/right lane 95<sup>th</sup> percentile queue increases from 443 feet to 770 feet in the PM Peak Hour



Central Avenue at Cedar Street

- Cedar Street southbound remains at LOS F in both the AM and PM Peak Hours, but increases in delay significantly
- Cedar Street southbound 95<sup>th</sup> percentile queue increases from 783 feet to 1515 feet in the AM Peak Hour and from 440 feet to 1745 feet in the PM Peak Hour

**Table 8 – Level of Service Results – 50% Detour (2015) – AM & PM Peak Hour (Signalized)**

INTERSECTION	AM Peak Hour					PM Peak Hour				
	LOS	Delay*	v/c	50th % Queue	95th % Queue	LOS	Delay*	v/c	50th % Queue	95th % Queue
<b>Chestnut Street at Elliot Street</b>										
Chestnut Street NB L/T/R	A	6.5	0.25	26'	137'	B	14.9	0.39	109'	242'
Chestnut Street SB L/T/R	A	9.4	0.61	83	369	C	26.9	0.83	307	#773
Elliot Street EB L/T/R	C	24.4	0.38	20	86	F	127.3	1.15	270	#508
Elliot Street WB L/T/R	C	22.7	0.15	4	58	C	23.5	0.13	3	58
<b>Overall</b>	<b>B</b>	<b>11.5</b>				<b>D</b>	<b>48.1</b>			
<b>Chestnut Street at Oak Street</b>										
Chestnut Street NB L/T/R	B	13.9	0.67	64'	#400	D	36.2	0.93	131'	#651'
Chestnut Street SB L/T/R	A	8.4	0.25	23	100	B	10.7	0.36	50	207
Oak Street EB L/T/R	C	22.6	0.35	7	88	C	25.4	0.60	22	164
Oak Street WB L/T/R	C	21.7	0.17	6	22	C	19.9	0.12	8	20
<b>Overall</b>	<b>B</b>	<b>16.3</b>				<b>C</b>	<b>25.9</b>			
<b>Needham Street at Oak Street/Christina Street</b>										
Needham Street NB L	A	8.1	0.43	32'	73'	E	56.3	0.93	60'	#190'
Needham Street NB T/R	B	18.0	0.86	276	#512	B	13.6	0.77	229	376
Needham Street SB L	A	6.7	0.19	5	18	A	6.7	0.21	7	22
Needham Street SB T/R	A	9.2	0.58	130	213	B	14.1	0.79	233	386
Oak Street EB L/T	C	24.2	0.58	72	#143	C	29.8	0.73	109	#224
Oak Street EB R	B	19.8	0.22	0	59	F	147.3	1.23	304	#505
Christina Street WB L/T/R	D	42.5	0.87	137	#288	F	164.8	1.25	192	#344
<b>Overall</b>	<b>B</b>	<b>18.9</b>				<b>E</b>	<b>61.6</b>			
<b>Highland Avenue at Gould Street/Hunting Road</b>										
Hunting Road NB L/T	E	62.6	0.81	182'	#413	E	60.3	0.68	82'	#213'
Hunting Road NB R	C	27.3	0.35	51	123	C	34.9	0.42	48	123
Gould Street SB L	E	62.8	0.71	102	203	D	51.0	0.72	187	368
Gould Street SB T/R	E	58.8	0.66	100	201	E	60.5	0.85	218	#440
Highland Avenue EB L	E	63.9	0.65	60	#166	E	78.7	0.68	29	#108
Highland Avenue EB T/R	E	63.6	0.96	357	#725	D	42.8	0.75	253	#535
Highland Avenue WB L	E	67.2	0.88	241	#571	E	61.0	0.83	198	#405
Highland Avenue WB T/R	C	33.0	0.76	326	#665	D	48.0	0.87	461	#887
<b>Overall</b>	<b>D</b>	<b>49.4</b>				<b>D</b>	<b>48.4</b>			

\* Delay is expressed in seconds per vehicle

# - 95th percentile volume exceeds capacity, queue may be longer. Queue shown is maximum after 2 cycles.

**Table 9 – Level of Service Results – 50% Detour (2015) – AM & PM Peak Hour (Unsignalized)**

INTERSECTION	AM Peak Hour				PM Peak Hour			
	LOS	Delay*	v/c	95th % Queue	LOS	Delay*	v/c	95th % Queue
<b>Elliot Street at High Street</b>								
High Street SB L	B	10.7	0.12	10'	B	12.1	0.23	23'
Elliot Street EB L	A	0.0	0.00	0	A	0.0	0.00	0
<b>Elliot Street at Oak Street</b>								
Oak Street NB LTR	A	8.9	0.20	18'	B	10.1	0.31	33'
Elliot Street EB LTR	A	8.5	0.20	18	A	9.5	0.27	28
Elliot Street WB LTR	A	9.8	0.30	30	B	11.8	0.45	58
<b>Central Avenue at Cedar Street</b>								
Cedar Street SB L/R	F	**	12.9	1233'	F	**	3.50	1238'
Central Avenue EB L	B	14.4	0.63	115	B	10.8	0.28	30
<b>Central Avenue at Webster Street</b>								
Webster Street NB L/R	F	108.6	1.11	393'	F	104.5	1.03	263'
Central Avenue WB L	A	8.1	0.03	3	A	8.2	0.07	5
<b>Central Avenue at Gould Street</b>								
Gould Street NB L/R	D	27.0	0.78	193'	F	178.1	1.33	868'
Central Avenue WB L	A	8.0	0.03	3	A	7.8	0.03	3
<b>Central Avenue at Reservoir Street</b>								
Reservoir Street NB L/T/R	B	12.0	0.08	8'	C	21.3	0.55	83'
Reservoir Street SB L/T/R	A	8.8	0.06	5	A	9.0	0.03	3
Central Avenue EB L	A	7.4	0.02	3	A	7.3	0.01	0
Central Avenue WB L	A	7.7	0.01	0	A	8.2	0.01	0
* Delay is expressed in seconds per vehicle								
** Delay is greater than 300 seconds								

As can be seen in the tables above, Scenario 2 (50% Detour) results in additional deficiencies than those seen in the Existing conditions and are summarized below:

**Chestnut Street at Elliot Street**

- Elliot Street westbound degrades from LOS B to LOS C in the AM Peak Hour

**Chestnut Street at Oak Street**

- Chestnut Street northbound degrades from LOS B to LOS D in the PM Peak Hour
- Chestnut Street southbound degrades from LOS A to LOS B in the PM Peak Hour

**Needham Street at Oak Street/Christina Street**

- Overall intersection LOS degrades from LOS D to LOS E in the PM Peak Hour
- Needham Street northbound left-turn degrades from LOS B to LOS E in the PM Peak Hour
- Oak Street eastbound right-turn degrades from LOS B to LOS F in the PM Peak Hour
- Oak Street eastbound right-turn 95<sup>th</sup> percentile queue increases from 44 feet to 505 feet in the PM Peak Hour

#### Highland Avenue at Gould Street/Hunting Road

- Highland Avenue westbound through/right lane 95<sup>th</sup> percentile queue increases from 478 feet to 665 feet in the AM Peak Hour and from 443 feet to 887 feet in the PM Peak Hour

#### Central Avenue at Cedar Street

- Cedar Street southbound remains at LOS F in both the AM and PM Peak Hours, but increases in delay significantly
- Cedar Street southbound 95<sup>th</sup> percentile queue increases from 783 feet to 1233 feet in the AM Peak Hour and from 440 feet to 1238 feet in the PM Peak Hour
- Central Avenue eastbound degrade from LOS A to LOS B in both the AM and PM Peak Hours

#### Central Avenue at Gould Street

- Gould Street northbound 95<sup>th</sup> percentile queue increases from 483 feet to 868 feet in the PM Peak Hour

## CONCLUSIONS

The bridge closure introduces approximately 997 new vehicle trips along the detour routes in the AM peak hour, and 1086 new trips in the PM peak hour. The two detour scenarios evaluate operations for two separate conditions, one considered to be more significant impact (Scenario 1) and a second for an even split of traffic between the two detour routes (Scenario 2).

In Scenario 1 (100% Detour), when all truck traffic uses Detour 1 and all car traffic uses Detour 2, one intersection will be significantly impacted by the detoured traffic, while queues at two additional intersections will increase significantly. These significantly impacted intersections are highlighted below.

#### Central Avenue at Cedar Street

- Cedar Street southbound would remain a LOS F in both the AM and PM Peak Hours, but increases in delay significantly
- Cedar Street southbound 95<sup>th</sup> percentile queues would increase from 783 feet to 1515 feet in the AM Peak Hour and from 440 feet to 1745 feet in the PM Peak Hour

#### Needham Street at Oak Street/Christina Street

- Oak Street eastbound right-turn 95<sup>th</sup> percentile queues would increase from 44 feet to 367 feet in the PM Peak Hour

#### Highland Avenue at Gould Street/Hunting Road

- Highland Avenue westbound through/right lane 95<sup>th</sup> percentile queues would increase from 478 feet to 665 feet in the AM Peak Hour and from 443 feet to 887 feet in the PM Peak Hour

All remaining intersections will continue to operate relatively the same or better than existing conditions.

In Scenario 2 (50% Detour), when all truck traffic uses Detour 1 and car traffic is split evenly between Detour 1 and Detour 2, two intersections will be significantly impacted by the detoured traffic, while queues at two additional intersection will increase significantly. These significantly impacted intersections are highlighted below.

#### Central Avenue at Cedar Street

- Cedar Street southbound remains at LOS F in both the AM and PM Peak Hours, but increases in delay significantly
- Cedar Street southbound 95<sup>th</sup> percentile queues would increase from 783 feet to 1233 feet in the AM Peak Hour and from 440 feet to 1238 feet in the PM Peak Hour

#### Needham Street at Oak Street/Christina Street

- Overall intersection LOS degrades from LOS D to LOS E in the PM Peak Hour
- Needham Street northbound left-turn degrades from LOS B to LOS E in the PM Peak Hour
- Oak Street eastbound right-turn degrades from LOS B to LOS F in the PM Peak Hour
- Oak Street eastbound right-turn 95<sup>th</sup> percentile queues would increase from 44 feet to 505 feet in the PM Peak Hour

#### Highland Avenue at Gould Street/Hunting Road

- Highland Avenue westbound through/right lane 95<sup>th</sup> percentile queues would increase from 478 feet to 665 feet in the AM Peak Hour and from 443 feet to 887 feet in the PM Peak Hour

#### Central Avenue at Gould Street

- Gould Street northbound 95<sup>th</sup> percentile queues would increase from 483 feet to 868 feet in the PM Peak Hour

All remaining intersections will continue to operate relatively similar to existing conditions.

As can be seen in the traffic analysis results tables, some of intersections impacted by detour operations will continue to operate relatively the same as existing conditions with minimal increases in delay or LOS during both peak periods on a typical weekday due to reduced turning traffic volumes. An exception would be at the intersection of Central Avenue and Cedar Street, which currently operates at LOS F with 95<sup>th</sup> percentile queues in excess of 400'. The delay and queuing conditions at this location will be significantly impacted due to the bridge closure diverted traffic, with significant queue lengths.

It is our opinion that the significant impacts at the intersection of Central Avenue and Cedar Street will considerably dissipate within a week or two of the bridge closure when a substantial percentage of drivers will seek alternate routes and avoid this area all together.

To manage detoured traffic, particularly during the initial bridge closure period, we recommend police detail be deployed during the morning and afternoon peak commuting periods for two weeks at the unsignalized intersection locations. In addition, we recommend field observations of the traffic conditions at the signalized intersections and adjusting the traffic signal timing as necessary.