## Appendix H

## Benefit Cost Memorandum



## Benefit-Cost Analysis

## I-44 Flood Study at Little Piney Creek

(Mile Marker 172.6 to 174.0)
Near the City of Jerome, Phelps County

May 2, 2018
MoDOT Job No. J5I3182

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# MEMORANDUM <br> Missouri Department of Transportation 

DATE: $\quad$ May 1, 2018

| TO: | David Silvester <br> District Engineer |
| :--- | :--- |
| FROM: | Matthew Dawson <br> Project Engineer |
| SUBJECT: | Central District - Design <br> Interstate 44, Phelps County |
|  | Flood Study |
|  | Between Log Miles 172.6 and 174.0 |
|  | Job No. J5I3182 |
|  | Benefit-Cost Analysis |

## Purpose and Summary

The goal of this memorandum is to review the relative benefit-cost of two design options to address the recurrent flooding of I-44 at Little Piney Creek near Jerome, Missouri. Floods in 2013, 2015, and 2017 have led to successively higher record flood elevations resulting in overtopping of I-44 and multi-day closures. Given the rural setting of the project site the posted detour route starts in Rolla, ends in Springfield, and adds 31 miles and 48 minutes to a through trip.

A benefit-cost analysis has been performed to compare the cost and relative merits of raising mainline l-44 above flood elevation (Option 1) against constructing a new bridge over Little Piney Creek to connect Arlington Outer Road east of the creek to South Outer Road west of the creek (Option 2). With l-44 being the second most used corridor in the state the current hydraulic conditions were analyzed for both alternatives to minimize the chance of future I-44 closures at this location. Typical design per the EPG would require the roadway to be placed at or above the 100 year storm event plus 1 foot of freeboard which is barely above the high water mark from 2017 which was found to be equivalent to a 150 year event. To avoid impacting the existing l-44 bridges over Little Piney Creek the roadway was set to a flood elevation equivalent to the flood of record (April 2017) plus one foot of freeboard.

During emergency closure the posted detour adds approximately 31 mile and 48 minutes of adverse travel. With an ADT of 27,476 vehicles per day the daily benefit to having l-44 open is
approximately $\$ 800,000$. With similar benefits between the two options, primarily the reduced adverse travel during flood events, the initial construction costs of each alternative were compared. Raising l-44 was estimated to have an initial construction cost of $\$ 13.25$ million while connecting and upgrading South Outer Road has an initial cost of $\$ 53.50$ million. Factors beyond initial construction cost were also considered but all would further support raising l-44 and are only briefly discussed.

Based on this analysis it is recommended that raising l-44 (Option 1) be advanced as the preferred alternative for development of the concept report.

Attached as Appendix A are plan and profile exhibits for both options.

## Existing Conditions

I-44 is an east-west roadway through central Missouri traveling between St. Louis and Springfield before entering Oklahoma west of Joplin. The project site is located southeast of Jerome, Missouri and consists of four lanes of traffic, two in each direction, separated by an open turf median. Guardrail is present approaching and departing the existing l-44 bridges over Little Piney Creek to protect the safety barrier curb and steep side slopes. Little Piney Creek flows northwest under I-44 and merges into the Gasconade River near Jerome. Short-term flooding issues have impacted I-44 in this vicinity since its original construction. In the last 10 years, the frequency and duration of the flooding issues have been increasing. In 2013, a storm resulted in record flooding, up to five feet in depth, along a one-half mile section of $\mathrm{I}-44$, closing the interstate. In 2015, a new record flood event eclipsed the 2013 flood, inundating the interstate by six feet, forcing a three day closure. In 2017, a new record flood overtopped the interstate by up to eight feet in depth, forcing a longer closure.

| DESIGN TRAFFIC |  |
| :--- | :--- |
| AADT (Existing) | $=27,476$ |
| \% Passenger Cars | $=26.5 \%$ |
| \%Single Unit/Panel Trucks \& Buses | $=52.2 \%$ |
| \% Multi-Unit Trucks | $=21.3 \%$ |
| Operational (Posted) Speed $=70 \mathrm{mph}$ |  |

Aerial photography and Lidar survey data were used in creating both design options. Limited field survey was also conducted to help establish computer simulation modeling of existing hydraulic conditions in Little Piney Creek. During design the project area should be surveyed to refine the roadway design and confirm impacts to the surrounding area.

## Hydraulic Design Parameters

With three progressively higher record floods at the project location since 2013 the design high water elevation was given careful consideration. Based on the EPG a typical design high-water
elevation would be the 100 year flood elevation plus 1 foot of freeboard or 696.84 at this location. However, the 2017 storm came just under this elevation at 696.55 which is approximately equivalent to a 150 year storm event. It is important to recognize that floodfrequency relationships are not static. While the 2017 flood is currently projected as a 150 year event, just a decade earlier it was considered to be greater than a 500 year event. Taking into consideration the trend of the last three record floods having increasing high-water elevations, the typical design standard may not be sufficient to reduce the frequency of floods resulting in road closure. For additional information on the existing hydraulic conditions see the progress report for the I-44 Flood Study, Hydrology and Hydraulics previously submitted in January 2018.

The Department expressed a desire to avoid impacting the existing l-44 bridges over Little Piney Creek since both structures have stayed above historic flood levels. Additionally, the potential benefit of a couple feet of additional freeboard would not justify the large cost of structure replacement. Instead, the roadway profile was examined to determine how high the roadway could be raised without impacting the existing structures. It was determined that the 2017 flood elevation plus 1 foot of freeboard would avoid impacting the structures while still accommodating a flood event in excess of the 2017 record (See Table 1).

Table 1 - Design Flood Elevations

| Storm Event | Flood <br> Elevation | Free- <br> Board | Design <br> Elevation | Notes |
| :--- | :---: | :---: | :---: | :--- |
|  |  |  |  |  |
| 100 Year | 695.84 | 1.00 | 696.84 | <-EPG Design |
| 2017 Flood | 696.55 |  |  | <-150 Year Flood Event |
| 150 Year <br> (Design Storm) | 696.55 | 1.00 | 697.55 | <-2017 + Freeboard |
| 500 Year | 699.95 | 1.00 | 700.95 | <-Too high, requires <br> bridge reconstruction |

## Option 1 - Raising l-44

Option 1 involves reconstructing a segment of I-44 at or above the design elevation of 697.55 while not impacting either existing l-44 bridge over Little Piney Creek. The proposed roadway profiles would begin to rise above existing just west of the structures with a new sag vertical curve. Coming out of the sag vertical curve in the westward direction, the profile grade would be $0 \%$ which is similar to the existing condition. Utilizing a $0 \%$ grade reduces the limits of improvement to the west, and helps to minimize depth of fill required to elevate the roadway. A second vertical curve is used to tie the tangent grade back into existing. This design has a maximum change in grade for l-44 of 7.5 feet above existing. Total length of reconstruction would be approximately 4,700 feet.

Foreslopes of 3:1 are used along the outsides of the roadway for most of the improvement before steepening to 2:1 at the structures. Guardrail would be added where necessary to
protect the slopes, safety barrier curb, and other hazards. This approach helps keep the limits of the improvement tight to the roadway which reduces impacts to the floodplain and existing drainage ways at the foot of the existing roadway embankment. See Table 2 for additional design parameters used.

Table 2 - Option 1 Roadway Design Parameters

| Design Parameter | Design Value |
| :--- | :--- |
| Design Speed | 70 MPH |
| Lanes | 2-12' Lanes in Each Direction |
| Shoulders | $10^{\prime}$ Paved Inside $/ 4^{\prime}$ Paved Outside |
| Pavement | $17^{\prime \prime} \mathrm{HMA}$ (for cost estimating) |
| Side Slopes | $3: 1 / 2: 1$ at Bridge |

## Construction Staging

A total of three staging options were reviewed with a varying number of lanes. The existing structures over Little Piney Creek provide only 38 feet of roadway width and are a key constraint for the multilane options. Based on staging costs and functionality for a short term condition the 2-Lane Alternative is recommended for construction of Option 1.

2-Lane Alternative: Construction will need to be staged by placing both directions of traffic on one side of the interstate to allow the other to be raised. Following completion of one side the traffic would be moved to the new pavement and the remaining side could be rebuilt. Temporary concrete barrier with glare screen would be used between the opposing directions of travel during two-way operations. New concrete crossovers would be located east and west of the work zone to facilitate the traffic switch over. Potential cross over locations are found east of the existing Little Piney Creek structures and west of the project between the Hog Hollow Road interchange and the l-44 bridges over the Tater Hollow tributary. This option would allow for wider lanes and shoulders compared to the other two options.

3-Lane Alternative: Similar to the 2-lane Alternative except a second travel lane would be provided in one direction. This alternative would require reconstruction of the l-44 shoulders to support traffic. Assuming that the existing bridges are not widened the roadway section on the bridge would consist of 2-11 feet lanes in one direction, 1-12 feet lane in the opposite direction, a 2 feet concrete barrier with 1 foot shoulders on either side, and no outer shoulders. The narrow width in the single lane direction ( 12 feet lane +1 foot barrier shoulder) and lack of outside shoulders would be a concern for the large volume of truck traffic through this area ( $52 \%$ Single-Unit/Panel Trucks \& Buses and $21 \%$ multi-unit trucks).

Looking at the existing traffic the AADT is about evenly split by direction meaning that one direction would experience a much higher delay than the other. If traffic volumes are directional by time of day a movable barrier or zipper system could allow the lane configuration to be changed to better meet the AM/PM shift in demand. However, these are more typical in urban areas where commuter traffic in the morning is heavy in one direction and then the
opposite occurs in the afternoon as they return home. Traffic is likely not directional enough for this to provide sufficient benefit to justify the added cost of a movable system.

4-Lane Alternative: Similar to the 2-Lane Alternative except two 11 feet lanes would be provided in each direction with a concrete barrier separating each direction of travel. This alternative would require reconstruction of the I-44 shoulders to support traffic along with widening in the median areas. A possible roadway cross section would consist of 4-11 feet wide lanes, 2 feet concrete barrier with 1 foot shoulders on either side, and 4 feet outside shoulders. The key constraint with this option is the existing 38 feet wide bridges over Little Piney Creek. Even by narrowing the outside shoulders to 2 feet a total width of 52 feet is needed to provide 4 lanes of traffic. The bridges could be widened by 14 feet to the inside but the existing hammerhead piers would make that difficult. Most likely new piers would need to be added adjacent to the existing ones to support the 14 feet of widening. This would need to occur on both structures to allow for the roadway work in both directions to be constructed.

## Proposed Structures

No structural work is expected for this option.

## Right of Way

No new right of way is expected to construct these improvements.

## Hydraulic Impact

There are two potential hydraulic impacts associated with this alternative. The first, is a loss of conveyance capacity along Tater Hollow Tributary which parallels I-44 on the north side before entering Little Piney Creek. Raising the roadway widens the embankment footprint (as shown in Figure 1) adding fill to the adjacent tributary floodplain. Analysis of the design found that the floodplain fill was limited to a short reach and the hydraulic impacts to Tater Hollow were minimal with a maximum rise in water elevation of +0.01 -feet from the modification. Water surface profiles along with the roadway profiles for this condition and the existing condition are shown in Figure 2 below. Note that the worst-case conveyance impacts (as shown) for Tater Hollow occur with a reduced tailwater and do not reflect the 2017 backwater flood event.

The second potential impact is a loss of hydraulic connectivity over the interstate. As demonstrated during the record flood events, when the Gasconade River floodwaters back up to l-44 they eventually pass over top of the interstate transferring large volumes of water from the north side to the south. Raising the roadway will prevent this connection and force all floodwater to pass through the l-44 bridges to reach the south side of the interstate. This change has potential to increase backwater and produce higher flood stages for the same flood event. Analysis of the 2017 flood found that the hydraulic capacity of the l-44 bridges would be large enough to transfer Gasconade River floodwaters without a significant backwater impact due to the extended timeframe. Ultimately, by the time the Gasconade River's peak reaches I44 a sufficient amount of volume has been transferred through the bridges to the south side such that the peak elevation remains unchanged between existing and proposed. Therefore, no change to the peak hydraulics of Little Piney Creek occurs with Option 1.


Figure 1 - Tater Hollow cross-section showing fill impacts on tributary with 100-year floodplain


Figure 2 - Tater Hollow and I-44 Profiles showing road raise and 100-year water surface profiles

## Option 2 - Outer Road Detour

Option 2 involves connecting Arlington Outer Road east of Little Piney Creek to South Outer Road west of the creek with a new two lane bridge south of I-44. South Outer Road would be reconstructed to allow for bridge construction and to keep the pavement above the design elevation of 697.55. Given the character of the land surrounding the alignment and bidirectional operation a design speed of 55 mph was selected which exceeds the speed of the existing geometric design features. In order to achieve 55 mph the two lane roadway needs to be reconstructed from the new creek bridge west to Hog Hollow Road to address the existing tight horizontal curves at the west end and sharp vertical curves throughout. Total length of construction would be approximately 9,000 feet.

Grading along the sides of the roadway would be a combination of straight grades and ditch sections to tie back into existing. Foreslopes would generally range from 3:1 to $2: 1$ with back slopes of 2:1 used in cut locations. See Table 3 for additional design parameters used.

Table 3 - Option 2 Roadway Design Parameters

| Design Parameter | Design Value |
| :---: | :---: |
| Design Speed | 55 MPH |
| Lanes | 2-12' Lanes - One in each direction |
| Shoulders | $2^{\prime}$ Paved - Inside and Outside |
| Pavement | 12" HMA (for cost estimating) |
| Side Slopes | Straight Slope - 3:1 / 2:1 at Bridges Ditch Section - 3:1 Fore/2:1 Back |

## Proposed Structures

A total of three bridges are required to connect the outer roads. Each bridge would be 28 feet wide from face to face of safety barrier curb to support 2-12 feet wide lanes and 2-2 feet wide shoulders. Proposed bridges include the following:

Little Piney Creek (1,600 Feet Long, 75 to 95 feet tall) - Estimated Cost \$20,000,000 Long bridge to connect Arlington Outer Road to South Outer Road over Little Piney Creek. Steel plate girder bridge with spans ranging from 150 feet - 250 feet. The longer spans were chosen to reduce the cost of the tall and expensive substructure units as well as limiting the hydraulic impact of the bridge. Additionally, these spans allow for new piers to stay out of the channel and railroad clear zone. The cost of the bridge was determined based on a similar project on Route 5 over Lake of the Ozarks which had similar span lengths, width and tall piers.

Eastern Railroad Bridge (300 Feet Long, 30 feet tall) - Estimated Cost \$1,400,000
Bridge over the eastern railroad track crossing. Embankment will be used between the creek bridge and this railroad bridge to help reduce costs. Structure is anticipated to be a three span prestressed concrete bridge approximately 300 feet in length with the substructure skewed to the tracks.


#### Abstract

Western Creek Bridge (100 Feet Long, 14 to 18 feet tall) - Estimated Cost \$400,000 Bridge over the creek east of Hog Hollow Road needed to allow straightening of the alignment for South Outer Road to provide a 55 mph design speed. Structure is anticipated to be a three span prestressed concrete bridge approximately 100 feet long with the substructure skewed to the direction of flow. A culvert was also evaluated, but due to the size and potential length resulting from the skew was eliminated from consideration.


An at-grade railroad crossing is proposed where the roadway crosses the existing tracks east of Hog Hollow Road. A grade separation was investigated but the cost to build the roadway up and over the tracks plus a bridge was deemed to be excessive and the profile grade to tie back in at Hog Hollow Road would be challenging. At this time flood events that require closure of mainline I-44 also block the railroad tracks east of this crossing. With the tracks also under water no trains should be present at the crossing during detour operations.

No westbound onramp to l-44 currently exists at the Hog Hollow Road interchange. The next existing westbound onramp is located 3.7 miles west on North Outer Road at the Highway J interchange. To avoid further impact to outer roads a new westbound access point only for emergency detour operations is proposed from North Outer Road at the off ramp from westbound I-44 east of Hog Hollow Road. There is not sufficient space for a standard on ramp to be developed due to a lack of acceleration distance. However, during an emergency detour event there would be no traffic on westbound I-44 approaching this access point allowing vehicles to accelerate directly on westbound I-44.

South Outer Road provides the sole means of access to several properties that will be impacted by these improvements. The existing connection to Groover Road will cut off by new embankment for the bridge over Little Piney Creek. To address this a new secondary road will be built to connect to Groover Road and to the eastern quarry entrance. Near the existing east quarry entrance is the start of a lower access road that runs east down closer to the creek to Glover Hollow. Embankment for the creek bridge requires that access to this road be relocated or that an additional 325 feet of bridge be built to span both crossings of the lower access road. Other approaches along South Outer Road will also be rebuilt to be match the grade of the proposed roadway.

## Construction Staging

Maintaining access to the properties along South Outer Road during construction will be challenging since the new roadway closely matches the existing location horizontally while deviating vertically in many locations. During design the staging will need to be closely reviewed to ensure access can be maintained. Options may include shifting the proposed alignment to allow more of the existing roadway pavement to still be used during staged construction and/or temporary pavement to widen the existing during construction. Temporary concrete barriers may be needed to protect drop offs between existing and proposed.

West of Little Piney Creek the proposed work ties into Arlington Outer Road near where the existing roadway curves west to head under I-44. Access to the northwest on Arlington Outer Road will be provided by a new intersection located north of the new creek bridge. From the creek, bridge vehicles would still need to travel 2.5 miles east along existing Arlington Outer Road to Sugar Tree Road where a full diamond interchange provides access to l-44. This section of existing Arlington Outer Road would likely need improvements to the pavement, shoulders, and roadside safety. Options to create a new connection to l-44 closer to the new creek crossing were reviewed but the existing terrain makes this impractical.

## Right of Way

Based on limited right of way information roughly 15 acres of new right of way will be needed to construct the new bridges, new access to Groover Road, and revised side slopes and ditches. The total area will likely grow once existing right of way is better established and the proposed improvements are refined.

## Hydraulic Impact

Under the Option 2 scenario, potential impacts are foreseen along Tater Hollow Tributary and Little Piney Creek as a result of the added bridge crossings. No impacts are anticipated from lost floodplain storage volume associated with Gasconade River flood conditions as the volume of fill is minimal when compared to the total floodplain storage volume. The potential hydraulic impacts are controlled by the proposed bridge openings, one on Little Piney Creek and one on Tater Hollow Tributary. Using structures with similar geometry to existing results in small impacts to the water surface profiles. Analysis of the design found the largest impact on water surface to be +0.26 -feet on Little Piney Creek. Less impact was found on Tater Hollow. Since floodplain regulations in Missouri allow up to 1-foot of water surface rise, the hydraulics analysis found that the proposed plan would be acceptable if submitted for permitting.


Figure 3 - Cross-section of new bridge over Little Piney Creek with 100-year water surface elevation

## ENVIRONMENTAL IMPACTS

Preliminary environmental screening identified possible concerns that would require additional investigation during design:

- Seven endangered species could be present in the project area and would require a biological survey.
- Two previously recorded archaeological sites may be encountered requiring an archaeological survey.
Option 2 is expected to have a greater chance of impacts due to the sections of new alignment and work in and near Little Piney Creek.


## PAVEMENT DESIGN

For cost estimating purposes the Mechanistic-Empirical Design Table for Project Scoping was used in determining potential pavement depths. Based on the existing volume of 5,839 multiunit trucks a day ( $21.3 \%$ of AADT) on I-44 would yield an asphalt thickness of 17 inches for the interstate pavement. Traffic on South Outer Road will be much lighter than I-44 except during an emergency detour. To accommodate the emergency detour, and existing truck traffic from the quarry, the pavement was assumed to be 12 inches of asphalt. Actual pavement selection will need to occur during design.

## Pavement Summary:

I-44 Mainline
17 Inches, Asphaltic Concrete Pavement SP125CLP
South Outer Road
12 Inches, Asphaltic Concrete Pavement SP125CLP or SP125BSM
Additionally, 2.5 miles of Arlington Outer Road east of the creek would be used as a part of the emergency detour and should be further evaluated during design. Existing conditions on this segment of roadway likely warrant corrective measures to ensure the roadway can support the heavy volume of emergency detour traffic.

## CONSTRUCTION COST COMPARISOIN

| ITEM NO. | DESCRIPTION | UNIT | UNIT PRICE | Option 1-1-44 |  | Option 2-Outer Road |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Quantity | Extension | Quantity | Extension |
| 2035500 | EMBANKMENT IN PLACE | CUYD | \$ 16.00 | 97500 | \$ 1,560,000 | 213200 | \$ 3,411,200 |
| 2036000 | COMPACTING EMBANKMENT | CUYD | \$ $\quad 5.89$ | 97500 | \$ 574,275 | 213200 | \$ 1,255,748 |
| 2063000 | CLASS 3 EXCAVATION | CUYD | \$ 38.93 | 3000 | \$ 116,790 | 96580 | \$ 3,759,860 |
| 2063100 | CLASS 3 EXCAVATION IN ROCK | CUYD | \$ 250.00 | 500 | \$ 125,000 | 10740 | \$ 2,685,000 |
| 3030600 | FURNISHING ROCK BASE MATERIAL | SQYD | \$ 16.96 | 22,713 | \$ 385,213 | 26,430 | \$ 448,253 |
| 3030610A | PLACING ROCK BASE | SQYD | \$ 7.70 | 22,713 | \$ 174,891 | 26,430 | \$ 203,511 |
| 3040506 | TYPE 5 AGGREGATE FOR BASE (6 IN. THICK) | SQYD | \$ 9.53 | 13,248 | \$ 126,254 | 4,709 | \$ 44,877 |
| 4010150 | TYPE A2 SHOULDER | SQYD | \$ 76.33 | 13,248 | \$ 1,011,220 | 4,709 | \$ 359,438 |
| 4030422 | 12 INCHES, ASPHALTIC CONCRETE PAVEMENT SP125CLP OR SP125BSM | SQYD | \$ 195.00 |  |  | 26,430 | \$ 5,153,850 |
| 4030427 | 17 INCHES, ASPHALTIC CONCRETE PAVEMENT SP125CLP | SQYD | \$ 220.00 | 22,713 | \$ 4,996,860 |  |  |
| 6064106 | ROADSIDE GUARD CABLE 3 STRAND (16 FT. POST SPACING) | LF | \$ 100.00 | 5,415 | \$ 541,500 |  |  |
| 6061010 | GUARDRAIL TYPE A | LF | \$ 17.00 | 2,857 | \$ 48,569 | 11,000 | \$ 187,000 |
| 6063015 | TYPE A CRASHWORTHY END TERMINAL | EA | \$ 2,200.00 | 3 | \$ 6,600 | 15 | \$ 33,000 |
| 6085008 | PAVED APPROACH, 8 IN. | SQYD | \$ 78.64 |  |  | 1,316 | \$ 103,491 |
| 6191000 | PAVEMENT EDGE TREATMENT | LF | \$ 0.75 | 17,000 | \$ 12,750 | 23,327 | \$ 17,495 |
|  |  |  |  |  |  |  |  |
| 2022010 | REMOVAL OF IMPROVEMENTS | LS | 3\% | 1 | \$ 226,370 | 1 | \$ 529,882 |
| 6181000 | MOBILIZATION | LS | 6\% | 1 | \$ 594,378 | 1 | \$ 2,399,556 |
| 6274000 | CONTRACTOR FURNISHED SURVEYING AND STAKING | LS | 1\% | 1 | \$ 99,063 | 1 | \$ 399,926 |
| ROADWAY SUB-TOTAL |  |  |  |  | \$ 10,599,733 |  | \$ 20,992,087 |
| -- | Bridge Over Little Piney Creek | EA | \$20,000,000 |  |  | 1 | \$20,000,000 |
| -- | Bridge Over East Railroad | EA | \$ 1,400,000 |  |  | 1 | \$ 1,400,000 |
| -- | Bridge Over West Creek | EA | \$ 400,000 |  |  | 1 | \$ 400,000 |
| STRUCTURE SUB-TOTAL |  |  |  |  | \$ |  | \$ 21,800,000 |
|  |  |  |  |  |  |  |  |
|  |  | 25\% | CONTINENCY |  | \$ 2,649,934 |  | \$10,698,022 |
|  |  |  |  |  |  |  |  |
|  | TOTAL ESTIMATED CONSTRUCTION COST |  |  |  | \$13,250,000 |  | \$53,500,000 |

## BENEFIT-COST ANALYSIS

Reoccurring record flooding of I-44 at the Little Piney Creek crossing has caused shutdowns of I44 between Log Miles 172.6 and 174.0 three times in the last five years. The flooding induced shutdowns of I-44 require interstate traffic to be detoured between Rolla and Springfield using state routes (US 63, US 65, and Route 360). Compared to staying on I-44 this detour adds 31 miles and 48 minutes to a through trip between these locations. The benefit of either Option 1 or Option 2 would be quantified by determining the daily monetary value of eliminating the adverse travel faced by detour traffic during any closure of I-44. Adverse travel costs are based on $\$ 0.55 /$ mile and $\$ 15 /$ hour for extra distance and time required to complete the detour. A rate of $\$ 15 /$ hour for travel time delay may be low considering that $21.3 \%$ of the traffic consists of multi-unit trucks and $52.2 \%$ is made up of panel trucks, busses, and single unit trucks. Since this large percentage of the total traffic is likely commercial in nature the true hourly cost for adverse travel may be higher.

The quantified benefit of $\$ 800,000$ per day for this resiliency is essentially the same for either alternative. Therefore, the alternative with the lowest initial cost would provide the highest benefit-cost ratio. Using this criteria, Option 1 to raise the profile of I-44 is the preferred alternative because it is expected to cost $\$ 40.25$ million less than constructing the Outer Road facility.

# Appendix A - Strip Maps 

Option 1 (2 Sheets)
Option 2 (5 Sheets)








