BROKEN ARROW

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TRANSPORTATION PLANNING AND POLICY REVIEW AND RECOMMENDATIONS

FINAL REPORT

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Section 1 – Introduction and Level-of-Service Analysis

This document presents discussion and summarizes recommendations concerning planning, design, and operational issues and transportation planning issues for Broken Arrow as presented by City staff. These issues relate to:

- Collector street placement and traffic calming in residential areas (Section 2)
- Implementing roadway widening to efficiently increase capacity (a review on the current design criteria for arterial roads) (Section 3)
- Use and design of roundabouts (Section 4)
- Benefit and feasibility of signal interconnection (Section 5)

The overall theme in response to these issues is that a rigid methodology does not allow for the flexibility needed to determine the most appropriate approach for a given project. Furthermore, there is an appropriate amount of planning that should go into every transportation project that considers that facility's role in context of the intended localized use and its role in the citywide transportation system. It is expected that this document, along with the completed level-of-service analysis, will greatly assist the City in establishing a framework from which sound planning and design decisions can be made.

Some factors that influenced the recommendations that follow include the high cost of fuel, which is not likely to abate, growing demand by the public for alternative modes of transportation (such as pedestrian and bicycling transportation), and the increasing costs of construction and development, and current trends in transportation planning (like context-sensitive solutions).

The discussion that follows should be viewed as a resource for City staff and City Council to assist in making decisions and determining policy regarding sound planning practices that balance safety, efficiency, and economics with the goal of providing a transportation system that meets the goals and desires of the people of Broken Arrow. The Land Subdivision Code, Engineering Construction Standards, Zoning Code and Comprehensive Plan as well as development of an Engineering Design Criteria Manual should incorporate the recommendations of this report as modified and approved by staff, council and the public and any other potential stakeholders.

Background

The backbone of the transportation system for the City of Broken Arrow is a system of grid arterial streets spaced at one-mile intervals. US-51 (Broken Arrow Expressway or "BAX") serves as a major freeway-level thoroughfare for the city. Its primary role for Broken Arrow commuters has been as a high-speed corridor providing access to Tulsa to the west. In this capacity, traffic patterns in Broken Arrow historically have been mainly north towards the BAX and then westbound along BAX in the morning rush hour, with patterns reversing during the evening rush hour.

This long-standing traffic pattern influenced policy for and planning of the improvement of the street network in that there was a long-standing emphasis on widening north-south arterials (such as Aspen Avenue and Elm Place) from 2-lane to 5-lane roadways. Secondary importance was placed on widening east-west arterials from 2-lane to 3-lane facilities (such as Houston

Street and Washington Street) . Typically east-west streets were seen as feeding traffic to the north-south arterials and not as future cross-city thoroughfares. Because of this, typical improvement projects for these arterials were from 2-lane to 3-lane (an exception was Kenosha, whose current 5- and 7-lane cross-section was mainly driven by and an extension of the heavy-commercial portion within Tulsa that has continued to expand eastward).

This approach of focusing on developing the City's arterial system to accommodate the BAX-oriented traffic patterns served Broken Arrow for many years. However, with the improvement of Highway 169 (Pearl Habor Expressway) along the west edge of Broken Arrow and the completion of the Creek Turnpike (Liberty Parkway) along the south and east edges in 2001, traffic patterns have shifted by becoming more concentric and balanced in all directions. This is evident by the change in average daily traffic (ADT) volumes for inner-city arterial streets over time as shown in the table below. Although north-south traffic continues to average higher, the gap between the directional traffic appears to be narrowing. The ADTs shown are averages over a 4-mile section of arterial roadway bounded by Olive Avenue on the west, 9th Street on the east, Kenosha Street on the north, and New Orleans Street on the south

Arterial Direction	2000	2004	2007	7-Year Average
North-South	353,650	371,700	362,300	362,500
East-West	336,450	351,600	355.900	348,000

Exhibit 1.1 – Arterial ADT Totals by Direction

With this shift in traffic patterns, it is recommended that the City take a new approach to transportation project planning that is less focused on north-south arterials and seeks to define each corridor's "best-use" within the City's network based on safety for all commuters (vehicular, bicycle, and pedestrian), future traffic volumes, and existing land uses and anticipated development. With the core of the city served by an established grid arterial system that is ringed by freeway-type corridors, Broken Arrow has the foundation for an efficiently-patterned transportation network that, with proper planning, should meet the transportation needs of the City well into the future.

Level-of-Service (LOS) Analysis

As part of this study, an analysis was completed to determine the existing LOS for Broken Arrow's arterial streets and intersections. For roadways, LOS is an indication of operating conditions based on daily volume of traffic compared to the theoretical capacity. The resulting LOS is expressed in letter grades "A" through "F". For the analysis, the values as shown in Exhibit A.1 in the appendix were used in determining LOS for arterial streets based on roadway types as shown on Map 1. For intersections, the LOS determination differs than that for roadways, mainly in that it is calculated based on peak-hour traffic. However, the LOS is still represented by letter grades "A" thru "F", which indicate the following intersection conditions:

LOS	Typical Condition
A	little or no delay
B	short traffic delays
C	average traffic delays
D	long traffic delays
E	very long traffic delays
F	extreme delays

A LOS analysis was completed for both existing and future conditions. Existing conditions are taken as those expected in the year 2010 based on straight-line growth from Year 2004 through Year 2007 traffic. Future conditions are for year 2015 and are projected based on straight-line growth from Year 2010 to Year 2015 based on Year 2004 to Year 2007 traffic. The results of the existing LOS analysis are shown on Maps 2 through 4 and for future LOS analysis are shown on Maps 5 through 7.

Section 2 - Traffic Calming and Collector Street Placement in Residential Areas

Introduction

In context of the arterial/collector/local street system present in Broken Arrow, the collector streets that have evolved are a means of providing convenient access from residences and business to the surrounding arterial network. However, many collectors also serve a role as a residential street. In this aspect, a lot is demanded from the collector street. It is expected to efficiently gather and quickly deliver traffic to and from subdivisions, but have neighborhood characteristics such as fronting residential lots and on-street parking. This dual role creates conflicting usage that results in high-speed, high-volume traffic through residential neighborhoods.

The speeds experienced along a collector street are mainly a function of geometry. The street width is the primary factor but the horizontal and vertical alignments also strongly influence the ability of motorists to navigate a street at what they consider to be a safe speed. Design standards are provided in subdivision regulations and usually abide by widely-recognized engineering documents such as the AASHTO Green Book, which is a safety-based design manual. The main parameter is speed, but the design for a desired speed can produce a roadway capable of much higher operating speeds. In Broken Arrow, design speeds for collectors are 35 mph and minimum widths are 36'. The combination of these two design factors design produces streets that often can support speeds above 40 mph. The end result is a roadway that allows, and implicitly encourages, speeds above the posted speed limit of 25 mph.

Likewise, street volumes are mainly a function of street interconnectivity. The fewer the number of connecting streets and intersections, the fewer choices motorists have in choosing between different routes to and from their destination. This combined with having few access points to arterial streets creates conditions in which motorists are funneled onto a limited number of collector streets which often carry a disproportionate number of vehicles compared to other nearby streets.

One factor that lends to the development of residential areas that do not have adequate connectivity and therefore aggravates the speed and volume problem is the need to maximize the number of lots for a subdivision and for a given amount of land. The connectivity of the supporting street system is often secondary to minimizing the number of roads and pavement in general. The current City development regulations require two stub street connections per subdivision to promote interconnectivity between proposed and future developments. However, in some instances the size of the proposed development may benefit from additional stub connectors.

There are two approaches to developing a collector street system in Broken Arrow that demonstrates sound traffic calming practices. The first is to redefine the collector street's role by allowing and encouraging more non-residential uses along the mid-block collectors. In this scenario, the design standards for collectors are not modified, but direct residential frontage is discouraged. A potential downside is the tendency to disrupt the neighborhood continuum by dividing the whole-block subdivision into smaller blocks separated by the collector streets and non-residential uses along them. Also, citizens are typically opposed to non-residential uses (especially commercial) in the midst of what they perceive to be their neighborhood. Because of this, this is perhaps less likely for established neighborhoods but should be considered for potential mixed-used developments (such as the East Side proposal) in select areas of the city.

The second approach focuses less on land use and more on maintaining the collector's current primary role as a residential street and secondary role as a thoroughfare. For most traditional residential developments, this is usually the desirable approach. In this context, a collector system is a balance of interconnectivity and appropriate geometric design that inherently discourages high-speeds (above 30 mph). This is a simple concept but it is difficult to put in to practice because quantifying these concepts into a regulation document is somewhat subjective. Developers need to be aware o f design requirements to properly complete a due diligence to ensure financial feasibility of a project, and the challenge lies within providing a policy that states how to put connectivity into practice.

The following sections provide detailed discussion relating to traffic calming and street interconnectivity for Broken Arrow, followed by a summary of recommendations.

Traffic Calming

Straight and wide roadways in residential areas often attract traffic and encourage high speeds. The typical response has usually been reactive, in that after a build-out of a development and when the street is at its highest use, the speed problem becomes most apparent. The current practice is to enact traffic calming measures such speed humps, signage and marking, and increased enforcement. All of these measures are reactive and tend to be effective in the immediate vicinity of where they are applied. However, they lose effectiveness rapidly as the frequency between measures increases and as time passes and motorists become fatigued to the calming devices. There are several instances of this throughout Broken Arrow. A few include:

- Vicksburg Street, between Elm Street and 9th Street
- Lions Avenue, between Washington Street and New Orleans Street
- Fir Avenue, between Kenosha Street and Houston Street

A section of Vicksburg Street is shown below, which is fairly representative of all of these locations.

Exhibit 2.1 – Looking east along Vicksburg Street

As can be seen, Vicksburg Street is long, wide, and flat. Furthermore, this street is the one of only a few connecting continuous streets to the surrounding arterial streets within this subdivision. Because of these characteristics, Vicksburg experiences significant volumes with speeds mainly in the 30-35 mph range. Reactive traffic calming in the form of speed humps and signage have been enacted, but motorist obedience and law enforcement remains minimal.

A more successful design for this subdivision would have included more east-west connections to the surrounding arterial streets, use of narrower effective lane widths (not just overall street width, as discussed in the Existing Streets section below), and inclusion of geometric features (such as horizontal and vertical curvature) to self-enforce slower speeds.

In the effort to provide guidance in the application of techniques and measures to effect a more desirable collector street system, the following discussion addresses measures, design philosophies, and land planning to encourage a safe but efficient collector street planning and design. The treatment of existing and future streets is addressed separately as the measures for each are unique and different.

Existing Streets

Because it is not usually feasible or desirable to undertake major initiatives to enact traffic calming or change the characteristics of an existing street such as realignment or increasing interconnectivity, most measures recommended for existing streets are small-scale and low-cost. They will affect speeds more than volumes, as the traffic patterns for a given subdivision are established and cannot be changed significantly without major changes to the roadway network. They also should be measures that city personnel can enact in a timely and low-cost manner.

One of the most effective and feasible measures to lower operating speeds is to reduce the usable or effective lane widths. A lane width fitting with the desired 30 mph is 10-ft. For existing collector streets, which are typically 36-ft wide, the challenge is in how to enact this without rebuilding curbs or limiting uses of the street for all users (on-street parking and bicyclists). Effective lane widths can be reduced for both sides of the traveled lane by following the guidance below:

Curb-Side(Passenger Side): On-street parking should be accommodated as it in some respects provides for a traffic-calming effect. A typical width for an on-street parking area in along a residential street is 7 ft. It is usually not desirable to allow parking in a lane designated as a bike lane. However, it is also recognized that most bicyclists will use the area closest to the curb in the absence of parked vehicles. Therefore it is recommended that this area be delineated with striping but not specifically designated as a bike lane or for on-street parking. This provides for lane reduction while allowing the most flexibility in the use of the curb-side area.

Centerline (Driver Side): Opposing traffic should be separated by medians, centerline striping, and/or raised pavement markers. This is due to the fact that only reducing the lane width on the curbed side of the street (as discussed above) still provides for an perceived effective lane width of 20-ft to 24-ft in the absence of opposing traffic. In other words, without oncoming traffic, most motorists will drive close to the center of the street. A defined centerline designation will reduce the effective lane width under all conditions and keep the vehicle against the curbed-side of the lane.

Using these guidelines on effective lane width reduction along with other traffic calming measures and concepts, the following are recommended measures and practices to effect traffic calming along existing collector/residential streets in Broken Arrow:

- Traffic calming islands at intersections. Typical islands have a diameter of 5’ to 10’ and can be paved or landscaped (avoiding the use of trees or other hazardous obstructions)

- Curbed medians (typically 2 ft wide, with or without landscaping). Medians should only be placed in areas where on-street parking is not needed. This typically limits their use to sections with no fronting housing. In other areas where this is not practical, raised pavement markers or domes can be used to reduce the lane width and provide nearly the same effect while allowing for left-turning traffic and unimpeded driveway access.

- Speed humps.

- Additional signage and markings, including on-street markings enforcing posted speed limits.

Exhibit 2.2 demonstrates how a combination of these measures can be put into practice, using Lions Avenue as an example.

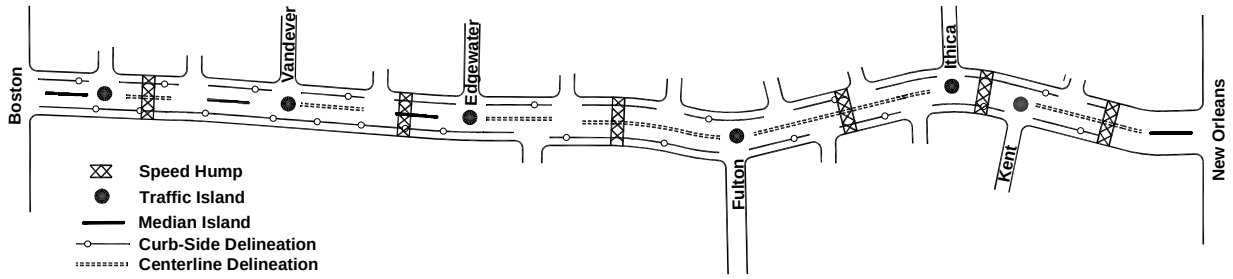


Exhibit 2.2 – Typical Traffic Calming Measures for Existing Streets (i.e., Lions Ave.)

It is emphasized that the effectiveness of traffic calming measures increases greatly when several different measures are used and as the distance between measures decreases. In other words, a successfully “calmed” street uses several different measures placed so that the motorist is being exposed to one measure or another for the entire length of the roadway. For this reason, traffic humps alone are not considered to be totally effective, typically only providing for very localized calming (around 100 feet before and after the hump).

Therefore, it is recommended that a mixture of these measures be installed so that the maximum spacing between hard measures (obstructions or physical devices such as speed humps, intersection islands, raised medians, etc.) is 200’ and a near-continuous length of soft measures (mainly striping and pavement markers) be provided.

Although these measures can have productive results, they are mainly reactive and cannot be expected to have as much influence as a properly-designed collector street, with traffic calming as a major design intent and end result. It should also be noted that the use of regulatory signs (such as stop signs) that are not warranted for traffic control or safety purposes and installed solely as an attempt to reduce speeds is discouraged. Such installations are often disregarded,

and when obeyed, only provide very localized speed reduction while increasing fuel consumption and air and noise pollution by making motorists stop or slow unnecessarily.

Collector Street Design and Placement

Another factor that influences traffic flow through residential areas is collector street design and placement. In this regard, the use of a given street as a collector to traffic is governed more by interconnectivity and length than by width. As stated in the introduction, many of the City's residential collectors serve dual roles that contradict each other. In order to resolve the conflicting usage and the following two main principles in collector street application should be followed:

1) Provide for greater connectivity and continuity of collector streets.
2) Make a distinction between Minor Collectors and Major Collectors, with each having separate purposes and applications.

The following discussion presents methods and guidance for collector street design and placement that is in following with these two principles.

Design
For design of collector streets, a distinction should be made between minor and major residential collectors. The minor collector would closely correlate with the City's current "High Density Minor" designation and the major collector would closely correlate with the "Residential Collector" designation. However, each would serve a distinct purpose and play a different role in providing for acceptable speeds and access from a typical heavily-developed residential subdivision. Clarification on recommended collector street standards and attributes are given below, whether in agreement with or different from the current standards:

<u>Minor Collector: Collects residential traffic and distributes to other collectors and arterial streets</u>
Design Features:
- Designed for maximum operating speed of 30 mph, mainly through geometric controls
- 26-ft width
- Allows for on-street parking and direct driveway access

Placement:
- A minimum of two north-south and two east-west Minor Collectors per mile-block
- Should be continuous from arterial intersection to interior major collector intersection (with full-block continuity desired)
- A minimum of two arterial connections per mile-block, located on either side of the Major Collector connection at approximately quarter-block ±500'

<u>Major Collector: Carries a higher-volume of traffic and inter-neighborhood bike traffic into the interior of the one-mile block and provide interconnectivity between arterial streets</u>
Design Features:
- Designed for maximum operating speed of 35 mph, mainly through traffic calming measures (including use of raised median islands and roundabouts at all collector intersections)
- 36-ft width
- Includes marked 6' bike lane on both sides of roadway (City should commit to regular street-sweeping of Major Collectors and other streets having marked bike lanes)

- On-street parking prohibited
- Direct driveway access allowed only by special exception

Placement:

- A minimum of one north-south and one east-west Major Collector per mile-block
- Should be continuous the entire length of the mile-block
- A minimum of one arterial connection per mile-block, located at half-block ±500 ft

A proposed typical section for the Major Collector is shown below.

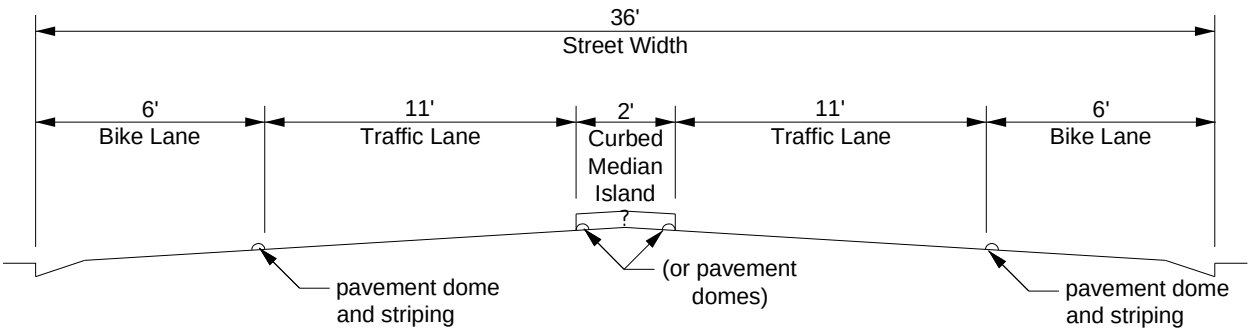


Exhibit 2.3 – Major Collector Street Typical Section

The following figure shows a desirable proposed one-block section taking into account the suggested placement guidelines, assuming predominantly residential uses on the interior and commercial along the arterials.

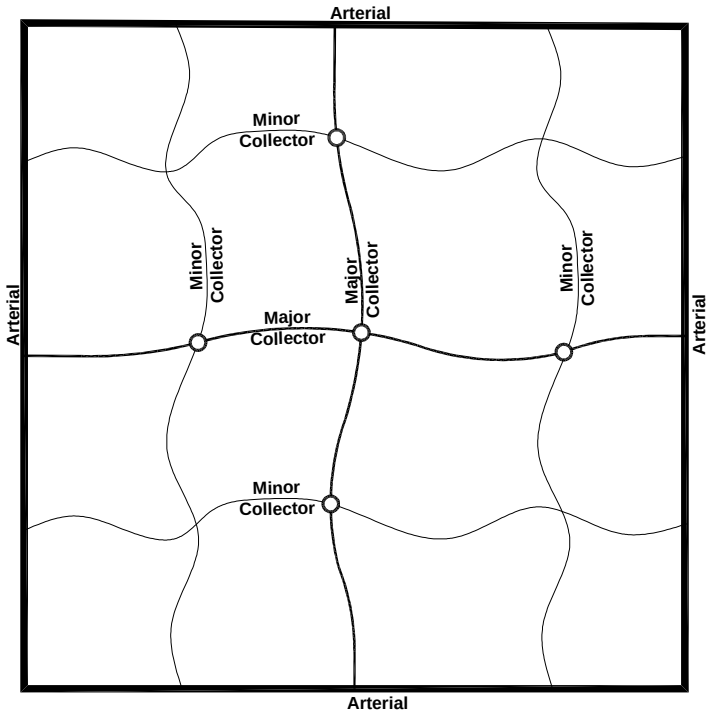


Exhibit 2.4 – Minimum Collector Street Placement and Configuration

Note that direct minor street connections to arterials should be either encouraged or discouraged based on the corridor classification for the arterial as described in the next section.

Street Connectivity

The measure of the ability of a street network to properly balance traffic loading can be determined through the ***connectivity index***. This is an objective factor measuring the quantity of roads and intersections within a given area. It is an indication of how well-balanced the system will collect and dissipate traffic. There are several methods by which to establish the index:

Method 1: The number of interior roadway segments divided by the number of all intersections (the closed end of cul-de-sacs are counted as an intersection.) Typical range is from 1.0 to 2.0. A higher value (above 1.4) is desirable.

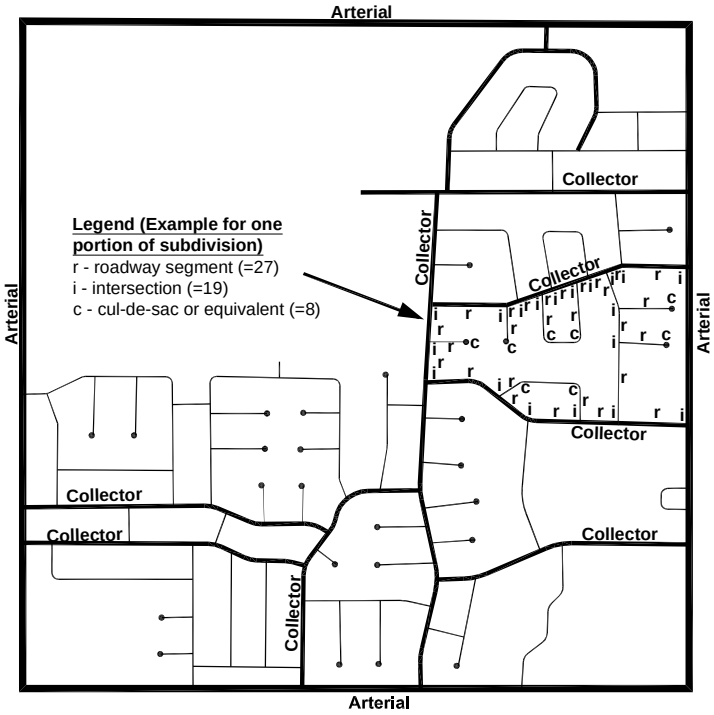
Method 2: The number of intersections divided by the sum of total intersections and cul-de-sacs, resulting in a number from 0 to 1 (loop streets are considered to the equivalent of two cul-de-sacs.) A higher value (above 0.75) is desirable.

Method 3: The total number of intersections within a defined area, such as the one-mile block (cul-de-sacs are not counted as intersections). A suggested goal using this method is 160 intersections per one-mile square (or 1 intersection per 4 acres.)

It should be noted that the connectivity index, especially that from Method 3, becomes less valid as the size of the development decreases. Because of this, the street connectivity concept should not be applied for developments less than 20 acres in size. Otherwise, a balanced approach for Broken Arrow may be to use all three methods, with the intent of requiring the CI goals to be met for two of the three given methods. It is recommended that with any development submittal, a traffic report be required that demonstrates how the proposal will meet connectivity goals and show anticipated traffic loadings per street and how those loads will be balanced. A discussion about the design intent and use of traffic calming or other measures to manage speeds should also be included. A weighted point system could be developed that takes the CI along with the six other suggested practices into account to grade a development's sound traffic planning principles.

The street systems shown in Exhibit 2.5 (which approximates the one-mile block containing Lions Avenue) demonstrate an example of putting these principles into practice for an existing neighborhood. The existing street layout is shown on top with a redesigned scenario shown underneath that strives to meet the goals as defined above. In the redesign, extra consideration has been given to the use of roundabouts by weighting their value in contribution to overall connectivity.

Existing Development



In the One-Mile Block:

Number of roadway segments: 176
Number of intersections: 107
Number of cul-de-sacs: 41

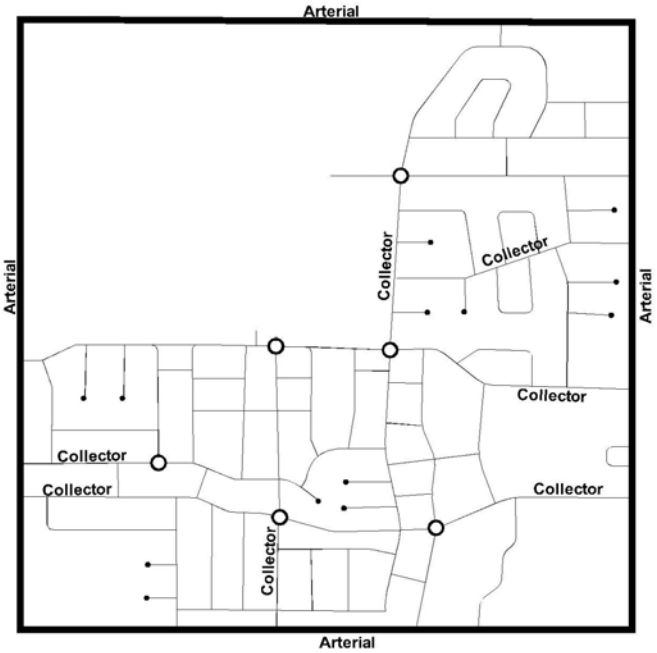
Resulting Connectivity Indices:

Method 1 (Goal = 1.4)
segments/(intersections+cul-de-sacs) or r/(i+c):
176/(107+41)=1.19 (85% of goal)

Method 2 (Goal = 0.75)
intersections/(intersections+cul-de-sacs)or i/(i+c):
107/(107+41) = 0.72 (96% of goal)

Method 3 (Goal = 1 int. / 4 acres)
intersections/acres of development:
107/480 acres = 0.22/acre
(1 per 4.4 acres = 89% of goal)

Redesigned Development



In the One-Mile Block:

Number of roadway segments: 206
Number of intersections: 120
Number of cul-de-sacs: 25

Resulting Connectivity Indices:

Method 1 (Goal = 1.4)
206/(120+25)=1.42(101% of goal)

Method 2 (Goal = 0.75)
120/(120+25)=0.83 (110% goal)

Method 3 (Goal = 1 int. / 4 acres)
120 / 480 acres = 0.25/acre
(1 per 4 acres = meets goal)

Exhibit 2.5 – Street Connectivity Example

Future Street Planning

For future street systems, an opportunity exists for proactive planning and design to encourage a street system that adequately balances volumes and speeds. The challenge is in developing a policy that meets this objective and is explicit enough to be understood by developers and enforceable by the City. To simply state "make streets more connected" will not suffice in that it does not provide an objective set of standards from which developers can adequately plan or design their developments. The following provides some guidance to help formulate regulations that can overcome this challenge.

A balanced and well-planned collector street system includes the following attributes:

1) **Provides several connections to the surrounding arterial system.** A subdivision with limited collector connections will funnel volumes to a small number of streets. More than one mid-block connection should be provided and continuity of collector streets should be enforced. A suggested goal is that for a given section of mile-block arterial roadway, one Major Collector be constructed that extends the entirety of the mile-block and two Minor Collectors be constructed that extend the majority (if not entirety) of the mile-block. The City's current policy of requiring two street stubs per subdivision and two access points per half-mile along arterials should be modified so the continuity of identified collectors is ensured and that the number of connection points is based on the size and perimeter of the proposed development.

2) **Allows flexibility in geometric characteristics,** such as encouragement for more dramatic horizontal and vertical alignment changes. Most streets are designed to comply with current engineering standards (i.e., AASHTO Green Book). Flexibility with these standards is encouraged to produce street designs with desired operating speeds (25 mph in residential areas. An example is reducing the minimum centerline radius from 350-ft to 200-ft for residential collector streets.)

3) **Use of roundabouts** at all collector-collector intersections **and traffic circles** at collector-local intersections. Guidance for design and application of roundabouts and traffic circles (intersection islands) is provided elsewhere in this document.

4) **Cul-de-sacs and loop streets are discouraged** since they tend to funnel traffic to a limited number of collectors. The use of an connectivity index (CI) or similar is encouraged as a means of providing a measurable standard for street interconnectivity.

5) **Land planning practices should regulate uses and access** to collector streets, especially residential driveway connections to Major Collector streets. The City is also encouraged to promote a variety of light-commercial and office uses within the mile-block residential areas and along the Major Collectors.

6) **Allowances for narrower collector streets** (such as 26') or measures that reduce effective lane widths for the majority of the street (as described in the Traffic Calming discussion above.)

Summary & Recommendations

The following provides a summary of the discussed recommendations in regards to traffic calming and collector street planning and design for Broken Arrow. Several of these measures will require modification of current subdivision regulations and street standards. The City is encouraged to work with developers, planners, and citizens to formulate goals and policy that meets the demands of all stakeholders.

- **Traffic calming for existing streets** can be enacted through a variety of measures that are low-cost and easy to install. These measures calm traffic by reducing effective lane widths and lowering the speeds at which motorists feel comfortable driving. The measures include intersection and median islands, speed humps, pavement markers and delineators, and additional signage and marking.

- **Traffic calming for future streets** should be inherent to the planning and design process of developments. This can be done by allowing for more flexibility in design standards, providing increased street connectivity, and encouraging the use of roundabouts at collector-collector intersections.

- **Proper street connectivity and collector street design and placement** can enhance desirable traffic characteristics through neighborhoods (low volume, low speed). The combined approach of providing for greater street interconnectivity while increasing collector street placement, access, and length is advocated as a means to achieve this result.

Section 3 - Arterial Improvement and Widening

Introduction

In response to current need and future growth, roadway widening is a necessary component of the on-going effort to improve Broken Arrow's transportation infrastructure. Traditionally, 2-lane rural roadways have been widened by adding a center left-turn lane and/or additional through traffic lanes, along with curb & gutter and sidewalks. The result is either a 3-lane or 5-lane roadway (as discussed in the Introduction section), which are the predominant roadway types throughout the city. This is fitting with the current Tulsa Area Major Thoroughfare Plan, which has classified all of Broken Arrow's arterial streets into several categories and established required cross-section characteristics and right-of-way widths for each classification.

Several considerations should be taken into account in determining the future arterial widening needs of Broken Arrow. These issues are:

- **The current update of regional long-range transportation plan** by INCOG, known as "Connections 2035". Expected to be completed in 2010, several citizen and stakeholder input phases have been completed and the results of these phases are taken into consideration in development of recommendations within this report. This is especially true for alternative modes of transportation, which are being increasingly demanded by commuters.

- **The completed level-of-service analysis** (as described in Section 1), which assists in defining existing operations and anticipated impacts on arterial roads and intersections from further development.

- **The economic impacts of street widening** due to increasing land acquisition and construction costs and the benefits of attempting to use existing street facilities and roadway widths to accommodate anticipated future traffic demand.

- **The current trend in transportation planning to identify the context of a given corridor** and to develop the corridor in manner best suited for that context (context sensitive solutions, or CSS). One objective of CSS is allowing for flexibility in design standards to address a localized constraint or to meet the unique needs of a particular project. This includes reviewing predominant land uses and anticipated zoning along the corridors and planning each corridor improvement to best support and facilitate those uses.

Corridor Classifications

With the above considerations in mind, a new approach to implement arterial development in Broken Arrow is being recommended. The current approach, as shown on the current Tulsa area Major Street and Highway Plan, is to identify classifications for arterials based mainly on level-of-service and without consideration of surrounding land uses or the existing context or future role of the corridor within the City's overall transportation infrastructure. A standard cross-section is three (3) to seven (7) lanes with curb & gutter and abutting sidewalks. As such, it is a lane-based classification to meet through-traffic level-of-service requirements and does so without consideration for existing land use or for alternative modes of transportation.

The suggested new approach involves looking at each arterial corridor independently and defining its "best-use" role within the overall transportation network. With this approach, arterials are separated into three (or more) categories, each serving a distinct and unique purpose. Cross-section design varies for each corridor type and even within each corridor depending on the particular context of that area. Features such as curb & gutter and two-way left-turn lanes are included on a case-by-case basis and only if warranted as determined in the project planning stage (as described later in this section). Right-of-way widths vary based on the inclusion of desired features for a particular corridor. The three recommended corridor categories for Broken Arrow are discussed below, with locations for the classifications summarized on Map 8. It should be noted that to effect some of these proposed recommendations would require deviation from the current Subdivision Regulations and Tulsa Area Major Road Plan. Therefore revisions to both documents would be needed to implement the recommended corridors to their fullest intent and purpose.

Parkway Corridor

Parkways serve to move traffic quickly and safely across the city. In essence they act as major arterials that collect other arterial traffic and provide direct access to freeways (such as US-169 and Creek Turnpike). Parkways have the following characteristics:

- Limited access to the surrounding street network (usually only at arterials and mid-block collectors)
- Approximate capacity is 25,000 vehicles per day per lane pair (one-lane in each direction)
- Operating speeds of 50-55 mph
- Separation between opposing traffic lanes with a curbed divided median
- Signalization is limited to arterial cross-streets
- Interchanges at either end (or nearby access) to connecting freeways
- Cross-section of 4 lanes with left-turn lanes only at warranted intersections. Paved 12-ft shoulders with ditch drainage (that can be converted to future traffic lanes as demand warrants). Sidewalks provided a minimum of 10-ft from nearest traffic lane (on opposite side of ditch.)

An example of a parkway corridor as constructed is shown below.

Exhibit 3.1 – Constructed Parkway Corridor

Exhibit 3.2 shows a recommended typical section for a parkway corridor. The range in values represents the flexibility needed for either retrofitting existing streets or other constraints (lower values) or for new routes (higher values desirable).

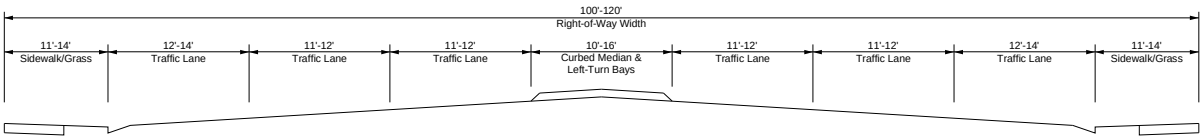


Exhibit 3.2 – Typical Section for Parkway Corridor

With the current transportation network for Broken Arrow, the City could benefit from parkway-type facilities halfway between the freeways that ring the city core. These would act as conduits for traffic deep within the city to quickly and directly access the freeway system and by doing so, remove freeway-bound traffic from the other arterials.

Ideal candidates for Parkway Corridors in Broken Arrow are:

North-south corridor(s)	**East-west corridor(s)**
Elm Place*	Omaha Street
	Washington Street (Garnett Road to Elm Place)
	New Orleans Street (Elm Place to Evans Road)

* -with consideration for future overpass at UP rail line

For a significant portion of the lengths of these roadways, there are existing two-way left-turn lanes. In these instances, the turn lane provides much of the same safety and capacity benefit of a curbed median island. For portions of those roadways that are planned to be improved in upcoming or future projects, it is recommended that the design reflect the use of a curbed median island in lieu of a center-left turn lane to better accommodate the corridor's role as described above.

In all cases for corridors designated as parkways, the following recommendations are being made in order to properly plan for the eventual improvement and upgrade of those corridors to parkway standards and in meeting with the characteristics as defined:

1) Access management and control practices should be strictly followed to avoid the unfettered proliferation of driveways and sidestreets connecting to these roadways. This can be done by encouraging shared driveways and access roads similar to frontage roads as properties develop along these corridors.

2) Land planning policies should be enacted to encourage land uses and zonings that do not require direct frontage or connection to the corridor.

3) Signals should be restricted to arterial intersections (no new signals along these corridors). Existing signals should be coordinated (as described in Section 4.)

Multi-use Corridor

Multi-use corridors are intended to primarily serve and promote alternative modes of transportation. They emphasis pedestrian and bicycle transportation over vehicular traffic. As such, they have the following characteristics:

- High-level access to surrounding street networks and residential areas
- Link pedestrian-oriented facilities throughout the city, such as parks, schools, community centers, and recreational facilities
- Operating speeds of 30-35 mph. Speeds are regulated by inclusion of traffic calming measures and proper planning and design of geometric characteristics to influence driver behavior
- Approximate capacity is 10,000 vehicles per day per lane pair (lane in each direction)
- Provide dedicated bike lanes and wide sidewalks. All appurtenances and facilities along these corridors (such as inlets, curbs, utilities) are placed with alternative modes of transportation in mind
- Signalization is timed for and uses detection specifically for pedestrian and bicycle traffic
- Cross-sections are 2 traffic lanes with 8-ft (min.) bike lanes and 10-ft sidewalks. Center left-turn lanes are discouraged; median islands can be installed for traffic calming and to provide left-turn access
- Bike lanes are provided in both directions, and sidewalk can be provided on one or both sides of the roadway.

An example of a multi-use corridor is shown below.

Exhibit 3.3 – Constructed Multi-Use Corridor

Exhibit 3.4 shows a recommended typical section for a multi-use corridor. The range in values represents the flexibility needed for either retrofitting existing streets or other constraints (lower values) or for new routes (higher values desirable).

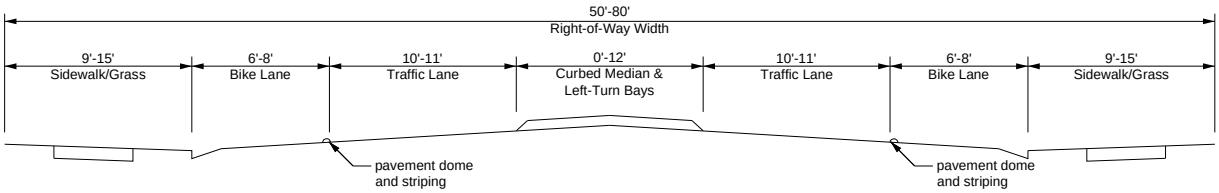


Exhibit 3.4 – Typical Section for Multi-Use Corridor

Logical multi-use corridors for Broken Arrow are:

North-south corridor(s)	**East-west corridor(s)**
Olive Avenue	Albany Street
9th Street	Washington Street (between Elm Place and Evans Road)
Evans Road	New Orleans Street (between Garnett Road and Elm Place)
	Jasper Street

It should be noted that although multi-use corridors are focused primarily on alternative modes of transportation, these modes should be considered in the development of all arterial corridors. The extent of alternative mode consideration for other corridors will be dependent upon the particular goals and existing operating conditions of each corridor and as identified during the planning stage.

Transitional Corridor

The primary role of a transitional corridor is to provide cross-city movement for vehicular traffic across the transportation network while allowing convenient access to fronting development. This is similar to many of the existing corridors throughout Broken Arrow. Although accommodating satisfactory levels-of-service for vehicular traffic is the primary consideration, these roadways can serve different mobility modes. They can also serve some of the functions of parkways and multi-use corridors as discussed elsewhere in this section. In this regard, they are "transitional" in nature. These roadways have the following characteristics:

- Vehicular traffic is primary mode of accommodation
- Access from the surrounding street network and fronting developments is lightly regulated. Center-left turn lanes are included along the entire length of the roadway. Commercial/retail is the predominant land use along these corridors.
- Operating speeds are 40-45 mph
- Approximate capacity is 13,000 vehicles per day per lane pair (lane in each direction)
- Signalization is provided at all arterial streets, most mid-block collectors, and at entrances into large commercial developments. These corridors typically benefit the most from signal coordination.
- Cross-section is four or six lanes with center turn lane, curb & gutters, and 6-ft sidewalks on both sides of roadway. Existing fronting development dictates that right-of-way needs be kept to a minimum.

An example of a transitional corridor as constructed is shown below.

Exhibit 3.5 – Constructed Transitional Corridor

Exhibit 3.6 shows a recommended typical section for a transitional corridor. The range in values represents the flexibility needed for either retrofitting existing streets or other constraints (lower values) or for new routes (higher values desirable).

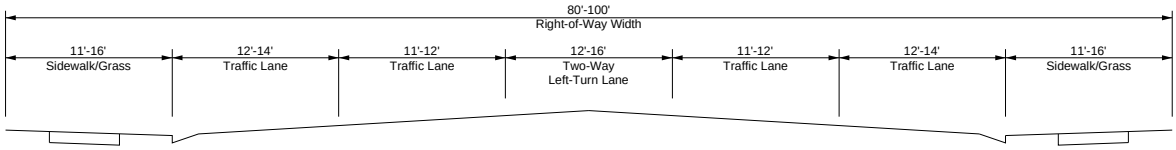


Exhibit 3.6 – Typical Section for Transitional Corridor

Likely candidates for the transitional corridor designation are:

North-south corridor(s)
Aspen Avenue
23rd Street

East-west corridor(s)
Kenosha Street
Houston Street
Florence Street
Tucson Street

Two-Way Left-Turn Lane (TWLTL) Recommendations

Most arterial widening projects in Broken Arrow have included installation of two-way left-turn lanes (TWLTLs), resulting in 3-lane and 5-lane improved cross-sections. TWLTLs can provide benefits in safety and traffic capacity as described in this section.

Although improvements have typically included the installation of TWLTLs, in some instances because of current land use and development, little benefit is gained from their presence. Because of this, some arterial TWLTL locations do not appear to be warranted. On the other hand, some arterial sections that would benefit greatly from TWLTLs because of volume and driveway density do not have them. To provide general guidance and recommendations on inclusion of TWLTLs for future arterial widening projects in Broken Arrow, the following discussion summarizes the benefits of TWLTLs (and median islands) and potential impacts to existing and future widening projects in Broken Arrow.

The primary benefit of TWLTLs is increasing roadway safety. Some studies have shown reduction in accident rates on roadways that have TWLTLs. One of the most comprehensive studies published in March 2008 by the FHWA indicated that the greatest benefit was realized for application of TWLTLs for two-lane rural roadways. Although this same study did not indicated the same benefit for urban streets, a Minnesota DOT study completed in the early 1990's demonstrated a considerable increase in safety in urban areas. Because these and various other studies have shown results to various degrees for different applications of TWLTLs, a few generalizations can be made concerning the safety benefits of their installation:

- TWLTLs can lower rear-end accident rates by separating slowing and stopping left-turn traffic from higher speed through-traffic.
- TWLTLs can lower right-angle and side-swipe accident rates by providing an area for left-turning vehicles to exit the through-traffic lane and wait for an acceptable gap in oncoming traffic. This reduces the tendency of left-turning traffic to make unsafe turns in front of oncoming traffic due to the motorists wanting to "clear the road" and not impede traffic behind them. It also reduces the amount of upstream lane-changing for through-traffic trying to avoid being impeded by the turning vehicle.
- TWLTLs can lower head-on accident rates by providing separation of opposing traffic, which can reduce the frequency of traffic crossing the centerline.

The first two benefits are largely a function of the amount of left-turning traffic, which is directly correlated to the number of access points (such as sidestreets and driveways/entrances) and intensity of fronting land use. The third safety benefit is mainly a function of opposing traffic flows, lane widths, and speeds and is less correlated to left-turning traffic. <u>In summary, TWLTLs can provide for a safer roadway, especially in areas with several access points and/or as the volume of left-turning traffic increases. However, as the number of traffic lanes and access points increases, raised medians become the preferred median treatment.</u>

A secondary benefit of constructing TWLTLs on a roadway is that capacity (and therefore level-of-service) is increased. This increase comes about by separating left-turning vehicles from the traffic flow that would otherwise block through-traffic by waiting for an acceptable gap in oncoming traffic. Using INCOG criteria for levels-of-service for different roadway cross-sections shows that the capacity of an arterial can be increased by approximately 5% (translating to between 500 and 2,000 vehicles per day) by including TWLTLs. The increase in capacity is strongly correlated to the amount of left-turning traffic and corresponding conflicting traffic. Again, the amount of left-turning traffic is strongly influenced by the amount of access points

along a corridor, either for streets or commercial driveways (residential driveways are largely negligible).

The main downside to construction of TWLTLs is in their costs. TWLTLs require additional right-of-way and roadway width. Broken Arrow currently requires a minimum TWLTL width of 15'. For a typical widening project this translates into an increase in right-of-way and pavement area of approximately 20%. Also, there may be peripheral adverse safety effects from TWLTLS in that for long stretches it can be used (illegally) as a passing lane. Some studies have shown that although the overall rate of accidents decreases with TWLTLs, the severity of the accidents increases. This may owe to the usage of long stretches of TWLTLs as passing lanes and also the increase frequency of head-on collisions from opposing left-turn vehicles entering in the TWLTL simultaneously. Therefore it is questionable as to whether the benefits of constructing TWLTLs are justified considering the additional costs and overall impacts to roadway safety.

Another component of the TWLTL issue is land planning and access management practices. Restricting land uses and access along a corridor generally increases the efficiency and safety of that corridor, which reduces the need for a TWLTL. However, these practices also tend to hinder development (especially commercial), which can create a disadvantage to property owners and developers. More often than not, access cannot be fully-managed without controls and regulations in place for a corridor that severely restrict driveway and sidestreet access. Once commercial uses and associated access proliferates along the corridor, the street and turning volumes increase and the need for the TWLTL becomes greater. Construction of the TWLTL encourages further development and access, and eventually a TWLTL becomes vital to the continued commercial vitality and development of the corridor. At this point the TWLTL is a necessity and eventual conversion to a median or in any way restricting access is not feasible.

An example of this is Kenosha Street, which because of its commercial nature benefits greatly from a TWLTL but with adverse impacts to safety and the ability of that corridor to quickly move traffic through the city. Alternately, some corridors that would benefit from TWLTLs or improved left-turning access do not currently have them. An example is the section of Kenosha Street between Elm Place and Main Street. This corridor is heavily commercial with many business driveways. Given this and the daily traffic on Kenosha, this would be an ideal candidate for a TWLTL (which is currently being proposed).

As it relates to roadway planning for Broken Arrow, **the safety and capacity benefits of providing separation of opposing traffic lanes typically justifies the increased costs in right-of-way and construction**. The separation can be achieved either by TWLTLs (recommended for transitional corridors) or median islands (recommended for parkway corridors). Multi-use corridors should not have TWLTLs but can have median islands for aesthetics and traffic calming purposes. For existing arterials that have been improved in the past, the impact from this recommendation is minimal. Most improved arterials have TWLTLs, whether warranted or not.

Reviewing the benefits and costs of TWLTLs in light of the recommendations made regarding different corridor classifications (parkway, transitional, and multi-use) for Broken Arrow arterial roadways, several suggestions are being made concerning TWLTLs/median islands for existing roadways and future widening projects. These recommendations are shown graphically on Map 9 (sections coded as shown below):

Parkway Corridors (median islands preferred)

P1 (high priority): TWLTLs do not exist but are proposed (in design). It is recommended that the design intent be advanced/revised to reflect the use of curbed median islands in lieu of TWLTLs, along with implementation of land use policy to manage access along corridor.

P2 (medium priority): TWLTLs currently exist. Plan for eventual conversion of TWLTLs to median islands to facilitate access management.

P3 (low priority): TWLTLs do not exist and are not proposed. Plan for eventual construction of median islands as volumes increase and funding becomes available.

Multi-use Corridors (TWLTLs not favorable, median islands acceptable)

M1 (high priority): TWLTLs do not exist but are proposed (in design). It is recommended that the design intent be advanced/revised to remove TWLTLs and that access management be implemented.

M2: (medium priority): TWLTLs currently exist. Plan for eventual conversion of TWLTLs to median islands or eventual conversion to thru-traffic lanes to allow for striping of bike lanes.

M3 (low priority): TWLTLs do not exist. Future widening projects should not include TWLTLs. Median islands (curbed or uncurbed) can be used for aesthetics and traffic calming.

Transitional Corridor (TWLTLs preferred)

T1 (high priority): TWLTLs do not exist but are warranted.

T2 (medium priority): TWLTLs do not exist but are likely to be warranted in the future as volumes. increase and fronting properties develop.

T3 (low priority): TWLTLs exist or are planned. No action necessary.

In conclusion, the decision of whether to include TWLTLs or median islands on arterials should be made on a case-by-case basis and in consideration of sound land planning and access management policies. The results of the Future Conditions Analysis study, along with the intent of Broken Arrow for future land planning and use, will help in determining specific locations where future TWLTLs/median islands should and should not be included in widening projects. Otherwise, for general planning purposes the following chart provides basic guidance on whether TWLTLs should be considered for an arterial corridor.

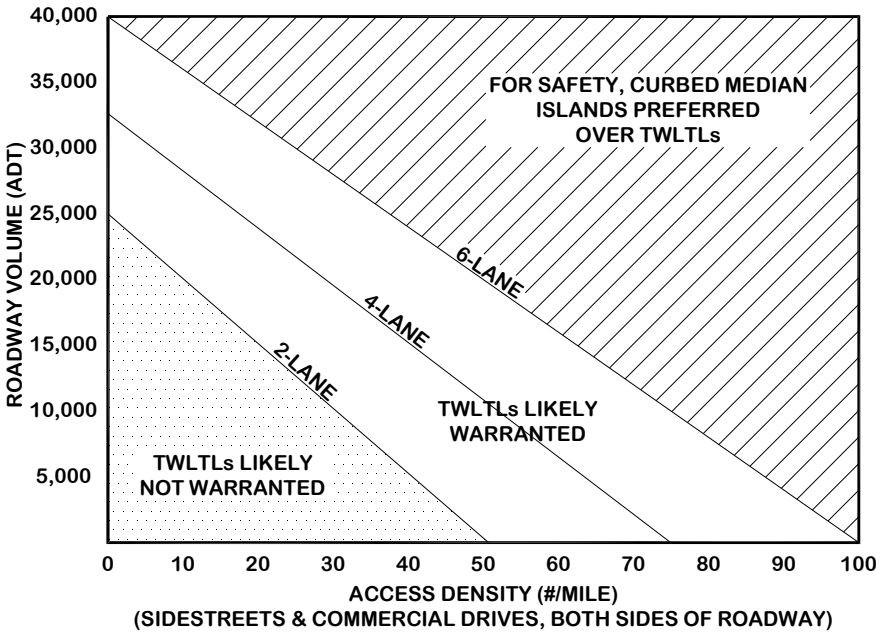


Exhibit 3.7 – Two-Way Left-Turn Lane Warrant

Roadway Widening Criteria

As discussed in the Introduction, the approach of Broken Arrow in completing roadway widening projects has been an emphasis on widening north-south corridors from 2-lane to 5-lane and east-west corridors from 2-lane to 3-lane. It was then suggested that because of shifts in traffic patterns, that a more prudent approach would be to plan for widening based on the corridor's planned best use within the city and expected future growth. This section provides information on cost comparisons between widening projects of differing cross-sections. Currently there are six relevant criteria stated in the current "Design Criteria for Arterial Roads" that serve to regulate the planning and design of roadway widening projects:

3.a.(1) Arterial streets with a width greater than two (2) lanes will have curb & gutter unless otherwise approved by City Council.
3.a.(2) Two lane streets will normally be widened to three lanes as an interim step.
3.a.(3) Three lane streets will normally be widened to five lanes as a final or interim step.
3.a.(4) Designs will require the minimum purchase of ROW.
3.a.(5) The designer will establish the width of the road based on level "C" service for the projected 10 year traffic loading for three lane and five lane interim roads.
3.a.(6) Final design width will be based on level c service for ultimate loading.

Discussion and recommendations concerning right-of-way acquisition, construction of curb & gutter, and required roadway lanes are presented below.

Right-of-Way (ROW) Acquisition

The Design Criteria indicates that the minimum purchase of ROW shall be required for design. Also, the City requires all developments to dedicate ROW for future use and roadway widening. Typically, for an arterial street the required dedication is 70 ft from centerline (140-ft total width) within 500 ft of an arterial intersection. Outside of this 500 ft, the ROW requirement is 60 ft from centerline (120-ft total width) for primary arterials and 50 ft from centerline (100-ft total width) for secondary arterials. Otherwise, if the needed ROW is not dedicated (i.e., the property has not been developed) by the time the widening project is initiated, the City typically purchases it from the property owner. At issue is whether it is feasible to acquire the total amount of right-of-way needed for the ultimate improved roadway when completing an interim widening project (5-10 years). A few generalities are presented for R.O.W. acquisition as it relates to arterial widening:

- As a corridor becomes more developed, the ROW acquisition and utility relocation costs become significantly higher. In this regards, it is suggested that there is benefit in acquiring the needed ROW for ultimate build-out. Furthermore, there is some justification for acquiring ROW far in advance of the design and construction stage.
- Concerning the policy of ROW dedication, the City is advised to study the equality of the current policy and possibility of enacting a revised policy whereby retroactive assessment is made of ROW acquisition fees for development that occurs within a limited timeframe of road improvements. This is basically a retroactive assessment of street fees, which currently is not assessed in Broken Arrow.

Curb & Gutter

The current Design Criteria mandate that any arterial widening project include installation of curb & gutter. The main benefit of adding curb & gutter to a roadway is to enclose drainage systems, which reduces right-of-way acquisition because wide, open ditches are not needed. The issue is whether installing curb & gutter as an interim measure (typically for 3-lane roadways) is prudent if there is a possibility that future widening (such as to a 5-lane section)

may be needed. The following recommendations are being made in this regard:

- The overall costs for widening from a 2-lane to a 5-lane ($6.0 million) are generally lower than widening a 2-lane to a 3-lane and then to a 5-lane in the future ($7.2 million). This is due to the demolition and reconstruction of existing curb & gutter and drainage systems needed for this widening scenario. In this regard, it is recommended that if a 5-lane or greater roadway appears to be justified within a 10-year horizon, the additional construction costs of a 5-lane improvement appear to be justified.
- A design alternative that would avoid rebuilding of draining systems is to size for ultimate widening and place the trunk line under the widened section of roadway (as opposed to two separate trunk lines under each curbline). Future widening would entail extending lines from inlet locations to relocated inlets. This would prevent complete rebuilding of drainage systems for future widening projects.
- The recommended corridor classifications can be used as a guide to determining level of improvements for the City's arterial streets. Given that the ultimate recommended lanes for each classification are as follows:

    - Parkway Corridor: 6-lanes w/median
    - Transitional Corridor: 4-lanes w/TWLTL
    - Multi-Use Corridor: 2-lanes w/bike lanes

  these ultimate typical sections can be used in conjunction with existing and future LOS analysis to determine whether curb & gutter should be installed. In following with this, curb & gutter would only be installed if the roadway was identified as needing improvement based on unsatisfactory future LOS and that improvement would need to be to the ultimate section as identified above to provide the needed LOS relief. In other words, if improvement was needed but not to the ultimate section, curb & gutter would not be required (although in following with the previous section, acquisition of right-of-way based on the ultimate section would be prudent).

Number of Lanes

The City has established a 10-year planning horizon and level-of-service criteria of "C" for determining the needed number of lanes for a widening project. Both are a valid and widely-used for establishing planning goals for a widening project. However, a few issues are noteworthy for establishing needed number of lanes:

- Typically an improved corridor will draw traffic from parallel corridors until the level-of-services are equal for the affected corridors. Therefore there is some temporary relief provided for parallel roadways that is not taken into account with the City's current criteria.
- The corridor-use concept as presented previously in this section should be considered along with needed lane requirements in order to adequately plan total roadway width (in consideration of potential median islands, TWLTLs, and bike lanes).

Widening Cost Comparison

Exhibit 3.8 is provided in order to assist the City of Broken Arrow in project budgeting and comparing planning concepts for different arterial widening scenarios.

Widening		Design, Right-of-way, & City Utility Relocation						Construction Cost		Total Project Costs (Rounded)			
		Design		R.O.W.			Utility	Without	With	Without Curbing		With Curbing	
From	To	(% of Const.)	Cost	Width	($/L.F.)	($/mile)	Relocation	Curbing	Curbing	Total	($/LF)	Total	($/LF)
2 lanes	3 lanes (inc. TWLTL)	8%	$ 140,400	60	$ 46.00	$ 242,880	$ 100,000	$ 1,755,000	$ 2,275,000	$ 2,240,000	$ 424	$ 2,760,000	$ 523
	4 lanes (undivided)	8%	$ 223,600	72	$ 100.00	$ 528,000	$ 125,000	$ 2,795,000	$ 3,380,000	$ 3,680,000	$ 697	$ 4,260,000	$ 807
	4 lanes & median	8%	$ 254,800	84	$ 150.00	$ 792,000	$ 150,000	$ 3,185,000	$ 3,835,000	$ 4,390,000	$ 831	$ 5,040,000	$ 955
	5 lanes (inc. TWLTL)	8%	$ 327,600	84	$ 150.00	$ 792,000	$ 150,000	$ 4,095,000	$ 4,745,000	$ 5,370,000	$ 1,017	$ 6,020,000	$ 1,140
	6 lanes (undivided)	8%	$ 421,200	100	$ 220.00	$ 1,161,600	$ 175,000	$ 5,265,000	$ 5,980,000	$ 7,030,000	$ 1,331	$ 7,740,000	$ 1,466
	6 lanes & median	8%	$ 457,600	120	$ 305.00	$ 1,610,400	$ 200,000	$ 5,720,000	$ 6,500,000	$ 7,990,000	$ 1,513	$ 8,770,000	$ 1,661
	7 lanes (inc. TWLTL)	8%	$ 535,600	120	$ 305.00	$ 1,610,400	$ 200,000	$ 6,695,000	$ 7,475,000	$ 9,050,000	$ 1,714	$ 9,830,000	$ 1,862
3 lanes (inc. TWLTL)	4 lanes (undivided)	9%	$ 134,550	72	$ 58.00	$ 306,240	$ 150,000	$ 1,495,000	$ 2,080,000	$ 2,090,000	$ 396	$ 2,680,000	$ 508
	4 lanes & median	9%	$ 274,950	84	$ 115.00	$ 607,200	$ 175,000	$ 3,055,000	$ 3,705,000	$ 4,120,000	$ 780	$ 4,770,000	$ 903
	5 lanes (inc. TWLTL)	9%	$ 251,550	84	$ 115.00	$ 607,200	$ 175,000	$ 2,795,000	$ 3,445,000	$ 3,830,000	$ 725	$ 4,480,000	$ 848
	6 lanes (undivided)	9%	$ 345,150	100	$ 190.00	$ 1,003,200	$ 200,000	$ 3,835,000	$ 4,550,000	$ 5,390,000	$ 1,021	$ 6,100,000	$ 1,155
	6 lanes & median	9%	$ 503,100	120	$ 285.00	$ 1,504,800	$ 250,000	$ 5,590,000	$ 6,370,000	$ 7,850,000	$ 1,487	$ 8,630,000	$ 1,634
	7 lanes (inc. TWLTL)	9%	$ 473,850	120	$ 285.00	$ 1,504,800	$ 250,000	$ 5,265,000	$ 6,045,000	$ 7,500,000	$ 1,420	$ 8,280,000	$ 1,568
5 lanes (inc. TWLTL)	6 lanes (undivided)	10%	$ 188,500	100	$ 88.00	$ 464,640	$ 250,000	$ 1,885,000	$ 2,600,000	$ 2,790,000	$ 528	$ 3,510,000	$ 665
	6 lanes & median	10%	$ 357,500	120	$ 195.00	$ 1,029,600	$ 300,000	$ 3,575,000	$ 4,355,000	$ 5,270,000	$ 998	$ 6,050,000	$ 1,146
	7 lanes (inc. TWLTL)	10%	$ 331,500	120	$ 195.00	$ 1,029,600	$ 300,000	$ 3,315,000	$ 4,095,000	$ 4,980,000	$ 943	$ 5,760,000	$ 1,091

Assumptions:

1) Existing 2-lane has roadway width of 22 ft and R.O.W. width of 50 ft
2) Existing 3-lane has roadway width of 39 ft and R.O.W. width of 60 ft
3) Existing 5-lane has roadway width of 73 ft and R.O.W. width of 84 ft
4) Costs shown do not include sidewalk. Sidewalk costs (both sides of road) are $350,000/mile

Exhibit 3.8 - Widening Cost for One-Mile of Arterial Roadway (Year 2010 Dollars)

Section 4 - Roundabout Planning and Design

Introduction

Traffic moving through an intersection has typically been controlled through the use of stop signs and traffic signals. Another available option that is relatively new to Oklahoma but gaining widespread popularity around the country is the roundabout.

Exhibit 4.1 - Typical Roundabout

It should be noted that what is shown is considered a ***modern roundabout***. A roundabout is a circular intersection but is not the same as a traffic circle or a rotary, which are either smaller or larger variations of a circular intersection, respectively. Traffic circles are usually a simple round island in the middle of a small intersection, usually installed on a local street within a neighborhood and mainly to provide traffic calming. Rotaries are large circular intersections with diameters usually greater than 300'. They appeared mainly before the 1960's but for various reasons never became prevalent and have since fallen out of favor (a local example of a rotary is at the intersection of Admiral Place and Mingo Road in Tulsa.)

For the purposes of this discussion, it should be assumed that the term "roundabout" refers to a modern roundabout and not these other variations. Traffic circles are briefly discussed as a traffic calming measure in Section 2. This section provides information, guidance, and recommendations on the planning and design of roundabouts in Broken Arrow with the intent of promoting consistency and safety in the future installation of roundabouts throughout the City.

Features of a Roundabout

Roundabouts have three main characteristics that distinguish them from traditional and other circular intersections:

1) **Entry Yielding** Vehicles in the circulatory roadway have right-of-way and entering vehicles must yield to these vehicles.
2) **Entry Deflection** Entering traffic is deflected to the right by splitter islands, placing vehicles in direct alignment with the circular roadway.

3) **Geometric Controls** All alignments and curbs are placed with the intent of controlling speeds to a desired threshold.

There are several reasons for the growing acceptance of roundabouts by the public, transportation officials, and safety officials. The factors leading to the consensus of those promoting the use of roundabouts have been confirmed by the vast majority of research studies conducted by transportation officials throughout the world. However, roundabouts are not appropriate in all cases and in some instances present disadvantages that have to be considered. The following is a comparison of the benefits and disadvantages of roundabouts compared to other forms of intersection control:

Benefits

Safety Due to the way vehicles approach and proceed through a roundabout, the types and severity of collisions are reduced. Before-and-after studies for roundabout installations have shown that the overall accident rate is reduced by about 40% and the number of injury/fatal accidents is reduced by 70%.

Geometry A roundabout can be an ideal solution to correct geometric problems at an intersection. An example of this is a five-legged intersection or one where one or more legs enters at a skewed angle.

Efficiency Depending on the traffic flows, a roundabout can yield a higher capacity than a signalized intersection. Also, the overall delay may be reduced as vehicles only have to stop if another vehicle is within the roundabout.

Access Roundabouts can improve access to properties near the intersection as they allow for u-turns and in some cases direct connection from the roundabout.

Sustainability Because vehicle starts and stops are generally reduced, fuel consumption and air pollution is reduced. Roundabouts also have no need for power (other than lighting) unlike signalized intersections. Overall asphalt area is usually reduced.

Aesthetics Roundabouts create an area suitable for landscaping or monument features, increasing the overall visual appeal of the area.

Disadvantages

Right-of-way Roundabouts usually require more right-of-way area in the immediate area of the intersection (However, they do not require turn lanes, which in some instances can actually lead to a decrease in the total amount of right-of-way needed for an intersection improvement).

Costs Upfront construction costs are usually higher than signalization.

Driver Unfamiliarity Drivers are generally not familiar with their operation, especially immediately after one is constructed. This can lead to driver confusion and sometimes a brief increase in accident rate.

Pedestrian and Bicyclist Access Roundabouts are considered by some to be pedestrian-unfriendly in that they require longer crossing distances and typically has traffic that is

constantly moving.

It should be noted that in most cases, there are ways to mitigate the disadvantages to the extent that its overall benefit is comparable to or greater than a signalized intersection.

Furthermore, there are some locations where roundabouts are not well-suited or make their design more challenging:

- Near signalized intersections (can lead to queues that can spill into the roundabout).
- Intersections with significant topography (sight-distance and drainage issues).
- Along corridors that have coordinated signals (disrupt platooned vehicles, reducing the effectiveness of coordination).
- Intersections with a large number of pedestrians or bicyclists (for the reasons given above).

Although any one of these conditions alone makes for a challenging design, a combination indicates the location may be an undesirable location for a roundabout. In any event, more care must be taken in the planning and design to justify that the benefits will outweigh the disadvantages.

Roundabouts in Broken Arrow

Because of the benefits described, it is recommended that Broken Arrow consider and allow the roundabout as an alternative to traditional forms of intersection control. However, because of their unique design and the fact that they are not yet common in the U.S. (and even less common in this region), general unfamiliarity is prevalent and little guidance is currently provided to assist developers, designers, city engineers and planners, construction inspectors, and law enforcement in their implementation and operation. Even among traffic planners and engineers, there is not universal consensus on the various issues related to their planning, design, and construction. Because of this lack of understanding and knowledge, a wide range of circular intersections of varying design have been constructed or are planned in Broken Arrow.

In a brief review of installed locations, it is obvious that the “no two are the same” adage applies. An example is the circular intersection of E. Jackson Place and S. Highlands Boulevard (shown below). At first glance it appears to be a roundabout and for all practical purposes it operates as one.

Exhibit 4.2 – E. Jackson Place and S. Highland Boulevard

The intersection has some of characteristics of a roundabout (such as signed entrance yielding),

but is also lacking in others (no flared splitter islands). Although there does not appear to be significant operating issues with this or any of the other roundabout locations (mainly due to the low volumes), many of them have shortfalls that could pose a safety issue. For instance, in this case sidewalk ramps for crossing S. Highland Boulevard encourage pedestrian crossings within the circulatory roadway, which is undesirable. Many of the design deficiencies apparent with existing installations can be avoided for future roundabouts by following the guidance provided in this section.

Planning & Design

It is emphasized that planning and design of roundabouts is a principle-based process, not a standards-based process. For this reason, a “one size fits all” approach is typically not appropriate and can in fact produce an unsafe design. This being said, for locations that are experiencing volumes much lower than theoretical capacity, many of the operating principles are not significant and in those cases, only safety is the primary consideration. In some instances, especially on low-volume, low-speed streets such as those found in neighborhoods or within private developments, if the three main features (entry yielding, entry deflection, and geometric controls) as described in the introduction are included, many of the complex details of the planning and design can be assumed and minimum design standards can be provided.

Because of this distinction in roundabout use mainly for aesthetic reasons along low-volume roads such as within a subdivision or apartment complex (referred to as an **aesthetic-oriented application**) and as a valid alternative to a more intensive intersection traditionally lending itself to all-way stop or signal control (referred to as a **operation-oriented application**), the guidance being provided to Broken Arrow is separated accordingly.

Operation-Oriented Applications

In general, a design template is not appropriate and a thorough feasibility study, planning analysis, and custom-engineered design should be completed for intersections that typically would be a candidate for all-way stop or signal control or is in some way considered “intensive” in operation. This would include the following locations at a minimum; other features considered unique to a particular intersection could also be justification for an in-depth planning and design process:

- more than one entry lane on any approach.
- intersections having volumes greater than the volumes listed for MUTCD Warrant 3 (peak-hour warrant), using the 70% factor, for the 1-lane/1-lane condition (i.e., greater than 700 total vehicles on the major approaches and 150 vehicles on the higher-volume minor approach.)
- a posted speed limit greater than 30 mph on any roadway leading to the intersection.
- more than 4 approaches or where an approach centerline is less than 75º from the centerline angle of any other approach.
- Any location within 500 ft of a signalized intersection or within 200 ft of a stop control condition along any approach.

In considering a roundabout as a valid alternative to traditional intersections, the following planning guidelines can be used in a precursory analysis of different intersection controls:

Roundabouts vs. two-way stops
A roundabout is unlikely to offer better performance in terms of lower overall delays than two-way stop control at intersections with minor movements (including cross street entry and major street left turns) that are not experiencing, nor predicted to experience, operational problems under two-way stop control.

Roundabouts vs. all-way stops
A roundabout will always produce a higher capacity and lower delays than AWSC operating with the same traffic volumes and right-of-way limitations.

Roundabouts vs. signals
The capacity of a single-lane roundabout may be assumed to be the MUTCD warranting volumes for signalization. Furthermore, a roundabout that operates within its capacity will generally produce lower delays than a signalized intersection operating with the same traffic volumes and right-of-way limitations.

Aesthetic-Oriented Applications

To assist Broken Arrow with providing guidance to developers and for reviewing development plans where a roundabout is proposed mainly for aesthetic reasons, a design standard showing minimums and clarifying the assumptions in its development and use is provided. A minimum design standard is provided in Exhibit 4.3. This is the equivalent of what is considered an “urban compact” roundabout (one of six general categories of roundabouts). The minimum design standards were developed with the following assumptions, which can be taken as minimum standards for any roundabout design submitted for consideration:

All roundabouts in Broken Arrow shall have:

- yield signs on all approaches and advance warning signs (roundabout ahead and 15 mph supplementary speed signs) installed approximately 200’ in advance of the yield signs.
- been designed using a bus as the design vehicle. Turning templates shall be submitted showing the turning movement in all directions.
- flared curbed splitter islands on all approaches.
- 15 mph as the maximum design speed.
- approach centerlines to the left or through the center of the roundabout island.

Summary and Further Guidance

In reviewing Broken Arrow’s street system in light of the recommended corridor classifications and taking the preceding discussion into consideration, the following suggestions are provided for roundabouts for general locations within Broken Arrow:

Arterial Streets
Arterial intersections in the city core (within the freeway ring) are for the most part signalized and retrofitting with roundabouts without good cause does not appear to be economically feasible. Also, their use along any corridor considered a candidate for coordination is discouraged. For some locations on the periphery of city traffic flow (such as the Elm Place

/Jasper Street intersection), roundabouts may be an attractive option. Other possible exceptions include eventual retrofitting of the Elm Place intersections with Washington Street and New Orleans Street, in which the roundabout would be suitable means for the proposed parkway/ multi-use corridor transition at these locations.

Collector Streets
Collector-collector intersections are usually good candidates for roundabouts, as well as any other intersection having or being considered for all-way stop control. Collector-local intersections will generally produce greater delay with roundabouts; at these locations, a traffic circle as described in Section 1 may be a more prudent option.

Local Streets
Other than for aesthetic or traffic calming measures, roundabouts generally do not provide any operational benefit and their use should be left to the discretion of the developer.

The estimated additional construction costs (beyond a typical four-leg intersection) associated with an aesthetic-oriented application is $50,000. This cost is mainly for the curbing and surface treatment for the splitter islands and center island. Also, the City should consider long-term maintenance costs associated with signing and island maintenance in determining the potential feasibility of roundabout placement. A recommendation for island treatment is geotextile with decorative rock placement.
This type of treatment reduces long-term maintenance typical with mowing but allows for eventual landscaping treatment by the City or residents.

Considering that most current sources of information on roundabouts is informational and suggestive in nature, the City is advised to refer to these sources for additional reference and guidance:

- ***Roundabouts, An Informational Guide***, FHWA.
- ***Kansas Roundabout Guide***, KDOT (the appendices provide thorough guidance on the feasibility studies and design submittal requirements suggested for operational-oriented applications. It is advised that for any projects that would call for an involved planning and design process, the breadth and depth of the submitted items required be as outlined in this guide).

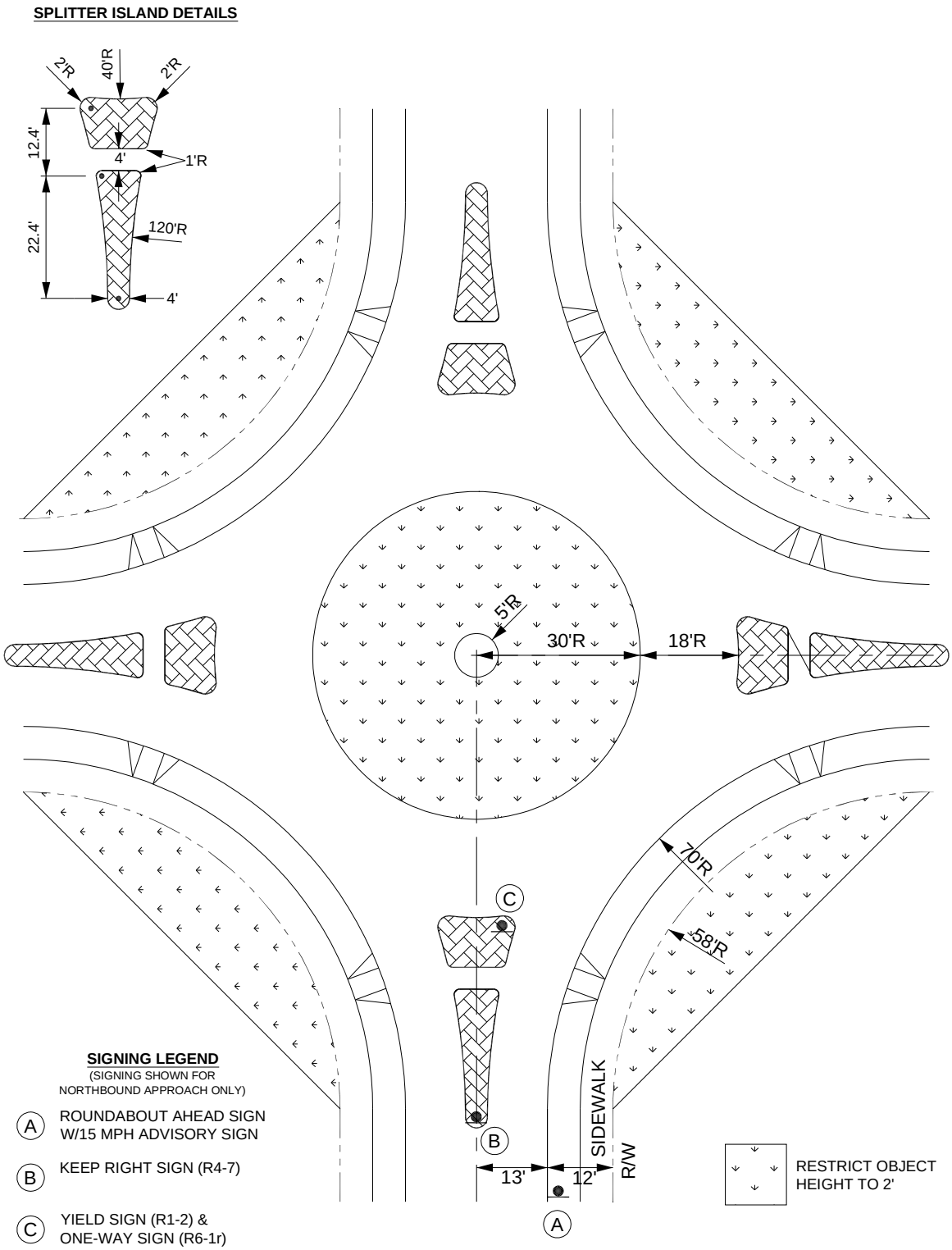


Exhibit 4.3 – Roundabout Minimum Design Standards (aesthetic-oriented application)

Section 5 - Signal Interconnectivity

Introduction

Currently there are approximately 70 signalized intersections within Broken Arrow. The large majority of these are along arterial streets, typically at arterial/arterial intersections. For some corridors, coordinating signals can provide great benefit to levels-of-service and corridor efficiency and safety. Traffic signal coordination can be defined as designing traffic signal timings to move platoons of traffic along a corridor with minimal delays. Coordinating of traffic signals reduces delay for the traveling public and improves the level of service and air quality.

Along a typical corridor, there are several characteristics that suggest the corridor would benefit from signal coordination:

- Closely-spaced signals, such as at freeway ramp/arterial locations. A standard rule-of-thumb is any signals located at or less than 500-ft from each other.
- There are few driveways and sidestreets to break up platoons moving between signals. Corridors with few access points between intersections can realize benefits from coordination with signal spacing up to one mile.
- Corridors where emphasis is placed on moving traffic quickly through a large portion of the city. A parkway corridor is a fitting example of this type of corridor. The ability of a high-capacity roadway to provide a quick route to end-point connections to freeways is enhanced with signal coordination.

Coordination of signals at or beyond one mile becomes problematic as costs required for communications increases and platoons tend to become dispersed during travel. A properly designed and implemented system will run in coordination only during peak hours, allowing for demand-responsive operations during off-peak hours. There are several means by which to coordinate signals:

Time-based Coordination Uses the internal clock of the traffic signal controller to coordinate signals along the corridor through different timing plans. This is an inexpensive method for coordinating signals, as it does not require additional installation of communications equipment and data cable between signals. The drawback for this type of coordination is the traffic signal controller clock needs to be set precisely with the other signal controllers a minimum of once a week (controller clocks tend to drift, disrupting the coordination). This becomes a maintenance issue as routine checking and adjustment is needed at each controller location to keep the system coordinated at optimal efficiency. Also, there are no means by which city personnel can monitor and communicate with the controllers from a remote location (such as the signal shop).

Hard-wire (Twisted Pair Copper/Fiber Optic) Uses a master controller to keep each signal along the corridor coordinated through constant communications with each local controller. This communication type is the most expensive because it requires cabling to be installed between all signals within a system. The least expensive option is overhead on existing poles, but this usually requires maintenance and operating agreements with the utilities that own the poles. Underground routing in conduit is most expensive but can be installed and maintained by city personnel or contractors (thereby avoiding utility agreements). Underground routing also becomes a maintenance issue as the underground cables are sometimes severed during construction or maintenance projects at other locations.

Wireless (Radio) Uses a master controller to keep each signal along the corridor coordinated through constant communications with each local controller. Wireless systems are typically less expensive than hard-wire interconnect. Generally radio systems need line of sight to work, which does not appear to be a significant issue for the corridors in Broken Arrow. Each intersection in the system has a radio with an antenna and communicates with the master controller. There are different types of wireless systems. Two common types are fixed frequency radio and short wave radio. The short wave radio system is typically the most economical system.

Of the three systems, the wireless coordination system would best fit Broken Arrow's coordination needs due to low-cost, ease of installation, use, and maintenance. For these reasons, wireless interconnect is the preferred communications method for the City of Tulsa. Short wave radio systems will work well along the City's arterial street grid system. The system will work with the existing traffic signal equipment with minor upgrades and can be deployed in a relatively short period of time.

A master controller can communicate with up to 20 to 25 signals or two different systems. The master controller can be located in an existing signal cabinet with sufficient room for a radio and master controller or it can be located remotely (at the City's traffic maintenance facility) and communicate via a phone or computer drop at one of the signal cabinets. Operating a master controller remotely via a phone or computer drop increases the City operational costs, but also allows the traffic signal technicians to monitor traffic signal in the system without having to travel to each intersection.

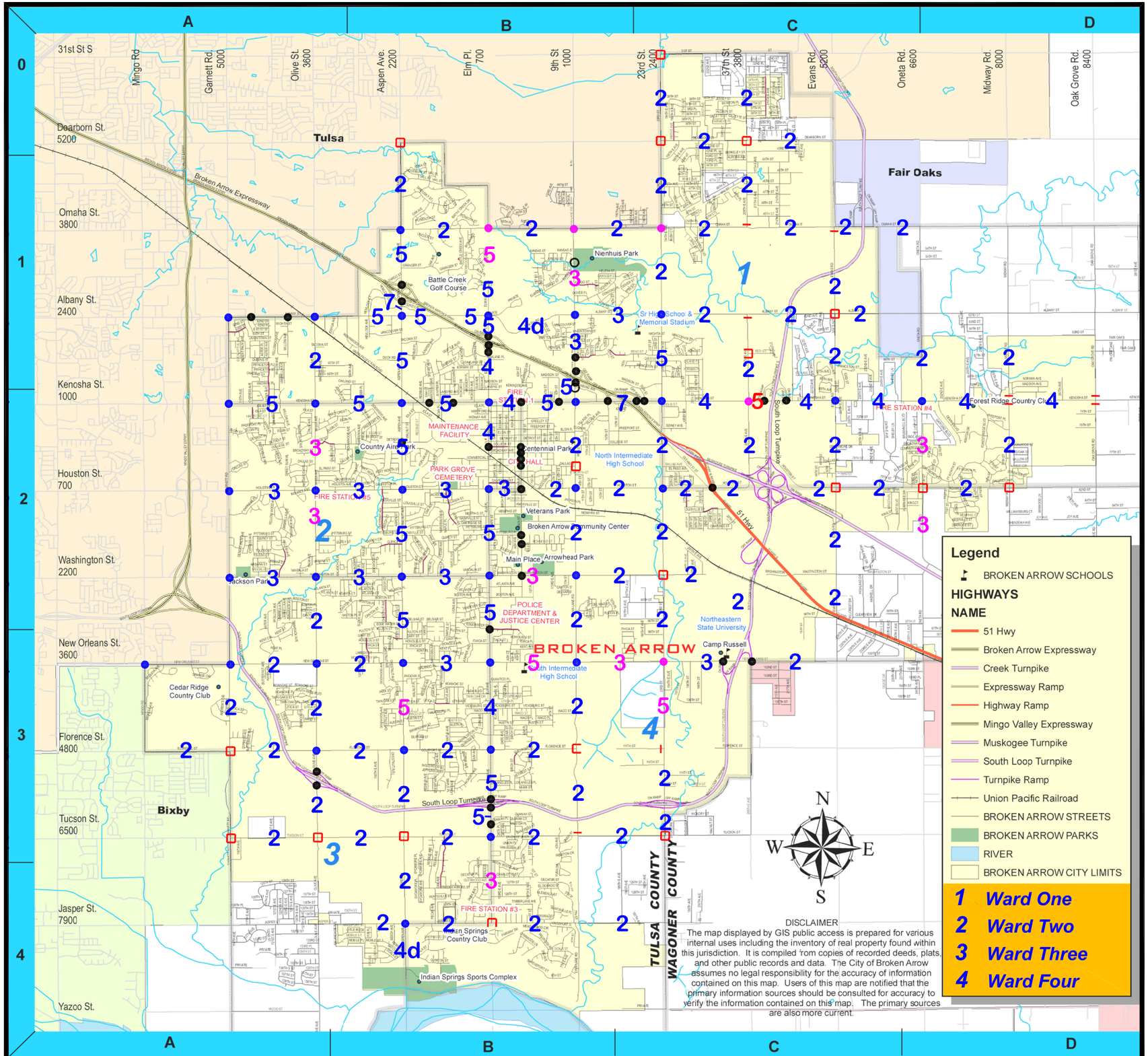
Costs for installing a wireless communication system involve purchasing a master controller to communicate the signals in the system and radios with antennas at each signal. Typical cost for a master controller and a master radio with an antenna is approximately $10,000 and typical costs for a local radio with an antenna is approximately $5,000 per intersection. Including costs for design and contractor installation, an approximate average costs per signal for a typical system is $13,000.

Recommendations

Corridors below are likely candidates for significantly improved operations if coordination is implemented. Priorities were developed based on costs, timelines for planning and design, and ease of construction. The estimate costs provided are for design and construction of coordination for all of the signals within each prioritized phase. This recommended signal interconnect plan is shown on Map 10.

First Priority (1-year)
Freeway ramp/arterial intersections along Broken Arrow Expressway
Signals along Main Street in downtown (coordinated for 15 mph)
15 signals = $200,000
Second Priority (2- to 3-year)
Kenosha Street corridor (w/possible interconnect to existing Tulsa system at Garnett Road) & freeway ramp/arterial intersections along South Creek Turnpike
20 signals = $250,000
Third Phase(3- to 5-year)
Elm Place, Washington Street / New Orleans Street, and Kenosha Street corridors
16 signals = $210,000

MAPS



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2008 TRAFFIC STUDY & STREET IMPROVEMENTS EVALUATION

MAP 1 ROADWAY & INTERSECTION INVENTORY

LEGEND

EXISTING	PROPOSED	ROADWAY
2	2	2-LANE (UNIMPROVED)
3	3	3-LANE (W/TWO-WAY LEFT)
4	4	4-LANE (UNDIVIDED)
4d	4d	4-LANE (DIVIDED)
5	5	5-LANE (W/TWO-WAY LEFT)
7	7	7-LANE (W/TWO-WAY LEFT)

		IINTERSECTION
●	●	SIGNALIZED (ARTERIAL)
●	○	SIGNALIZED (OTHER)
□		STOP-CONTROLLED (WITH STOP-CONTROLLED APPROACHES INDICATED)

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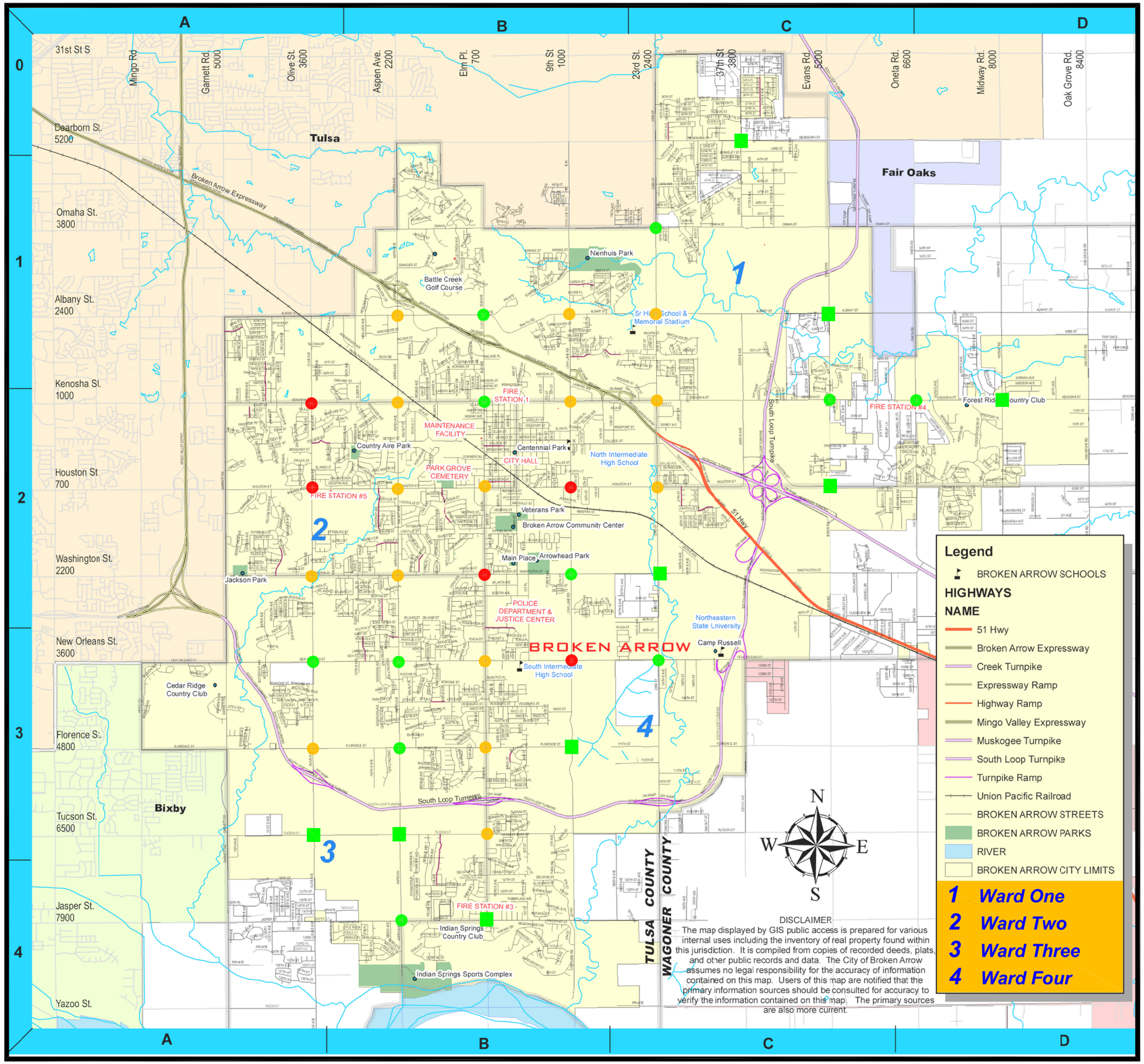

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MAP 2

YEAR 2010 INTERSECTION LEVELS-OF-SERVICE (AM)

LEGEND

SIGNALIZED	UNSIGNALIZED	LEVEL-OF-SERVICE
●	■	A, B, & C (ACCEPTABLE)
●	■	D & E (MARGINAL)
●	■	F (UNSATISFACTORY)

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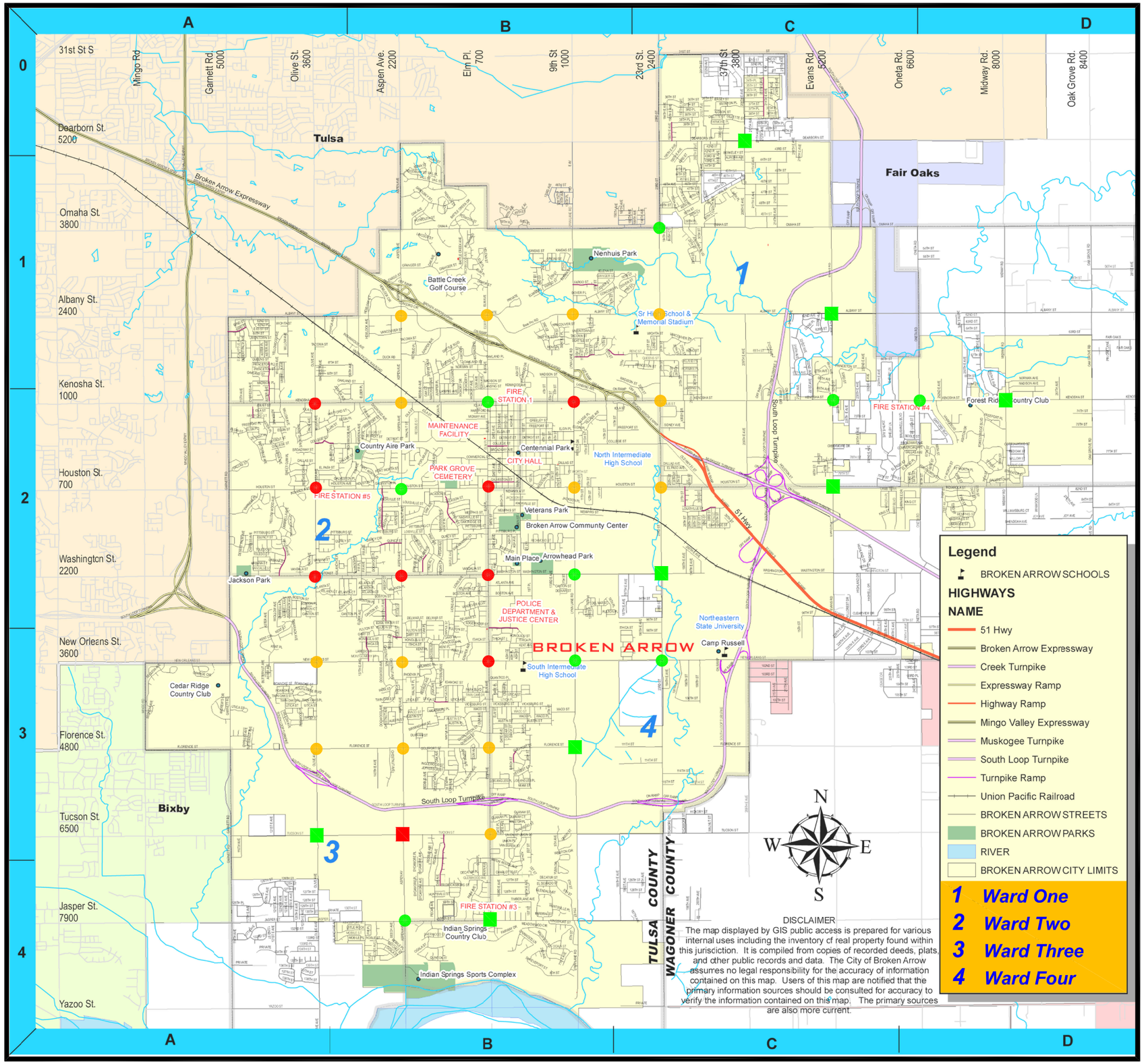

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MAP 3

YEAR 2010 INTERSECTION LEVELS-OF-SERVICE (PM)

LEGEND

SIGNALIZED	UNSIGNALIZED	LEVEL-OF-SERVICE
●	■	A, B, & C (ACCEPTABLE)
●	■	D & E (MARGINAL)
●	■	F (UNSATISFACTORY)

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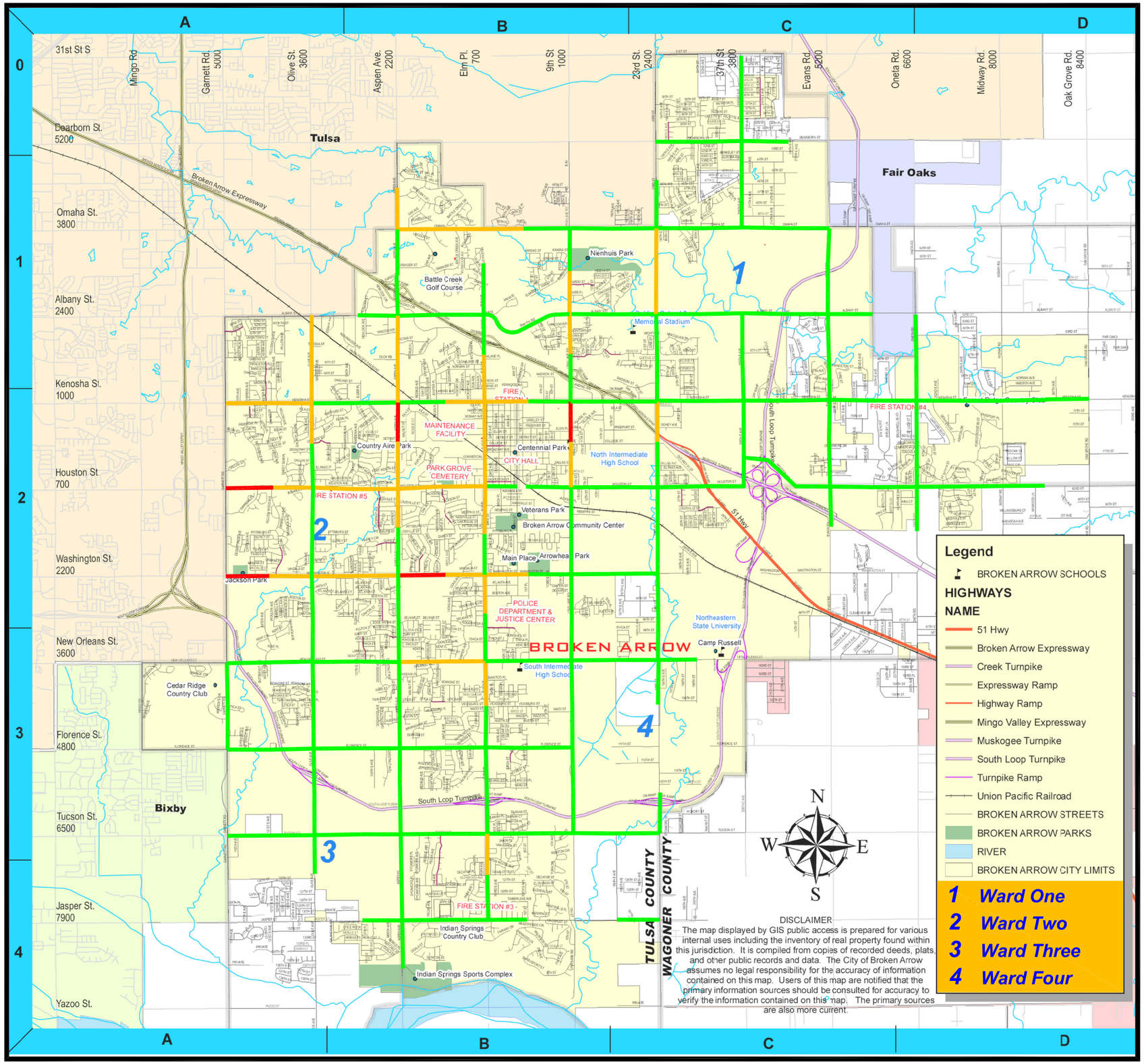

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MAP 4
YEAR 2010 ROADWAY LEVELS-OF-SERVICE

LEGEND

SEGMENT	LEVEL OF SERVICE
	A, B, & C (ACCEPTABLE)
	D & E (MARGINAL)
	F (UNSATISFACTORY)

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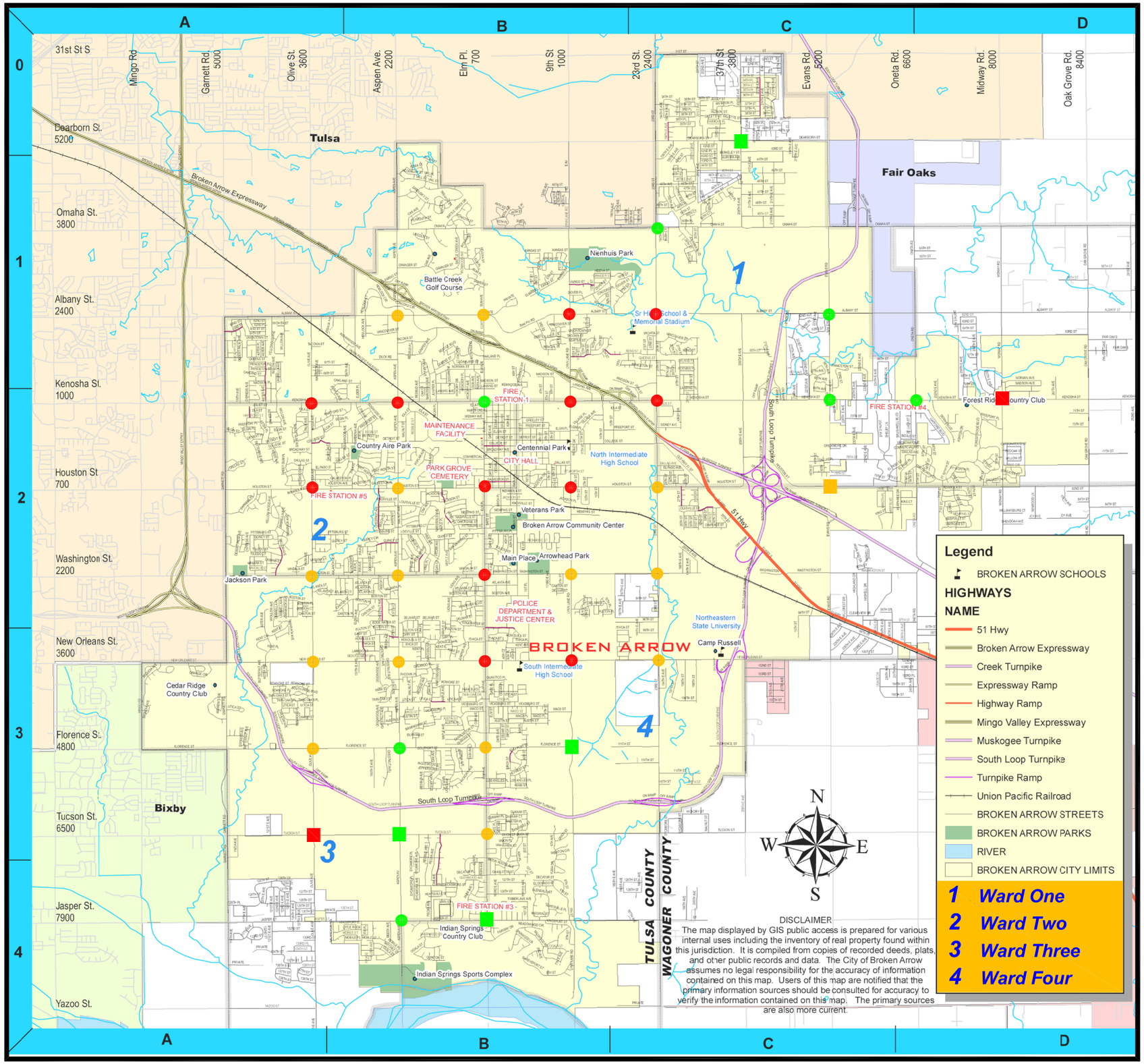

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MAP 5
YEAR 2015 INTERSECTION LEVELS-OF-SERVICE (AM)

LEGEND

SIGNALIZED	UNSIGNALIZED	LEVEL-OF-SERVICE
●	■	A, B, & C (ACCEPTABLE)
●	■	D & E (MARGINAL)
●	■	F (UNSATISFACTORY)

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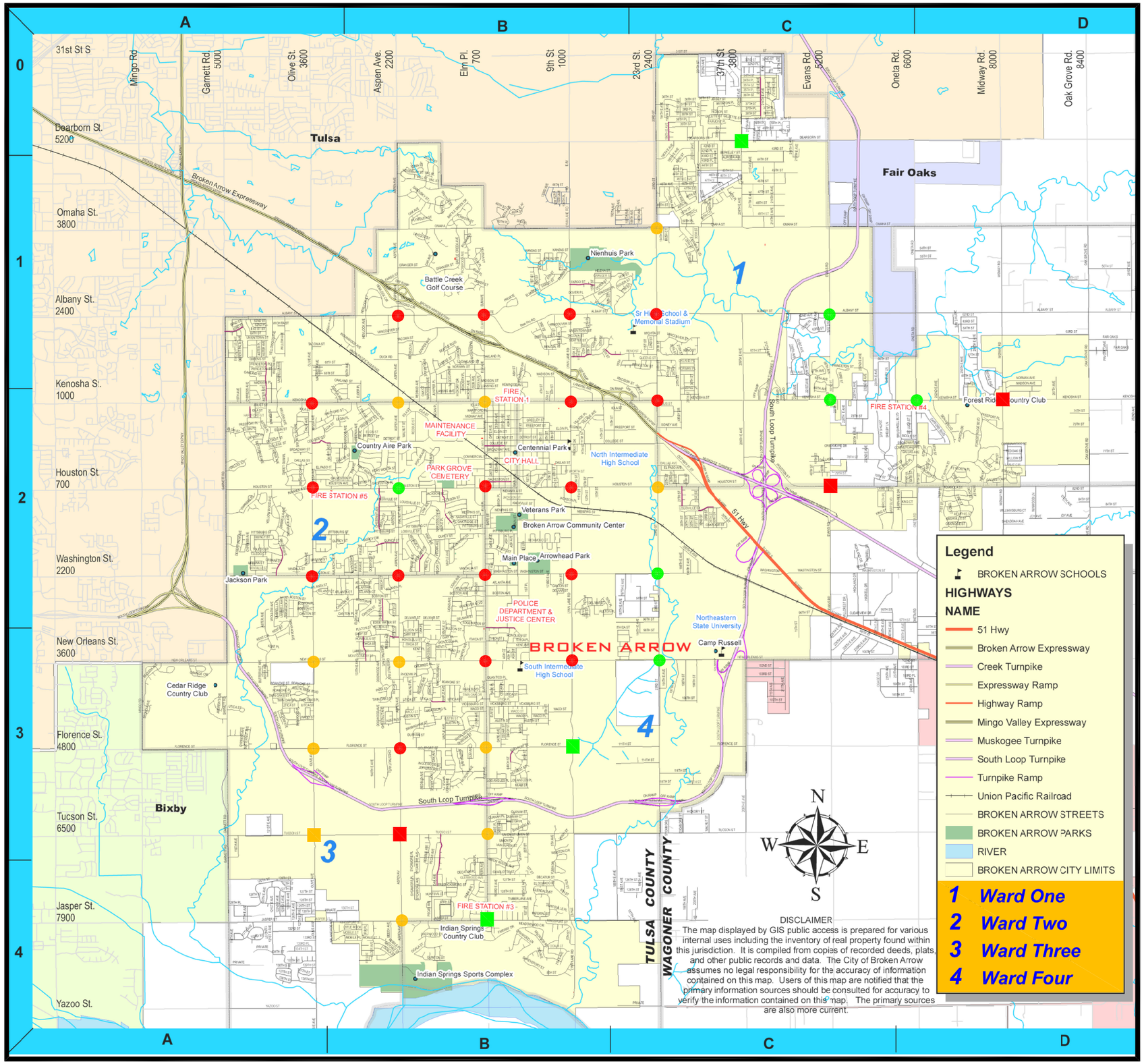

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MAP 6
YEAR 2015 INTERSECTION LEVELS-OF-SERVICE (PM)

LEGEND

SIGNALIZED	UNSIGNALIZED	LEVEL-OF-SERVICE
●	■	A, B, & C (ACCEPTABLE)
●	■	D & E (MARGINAL)
●	■	F (UNSATISFACTORY)

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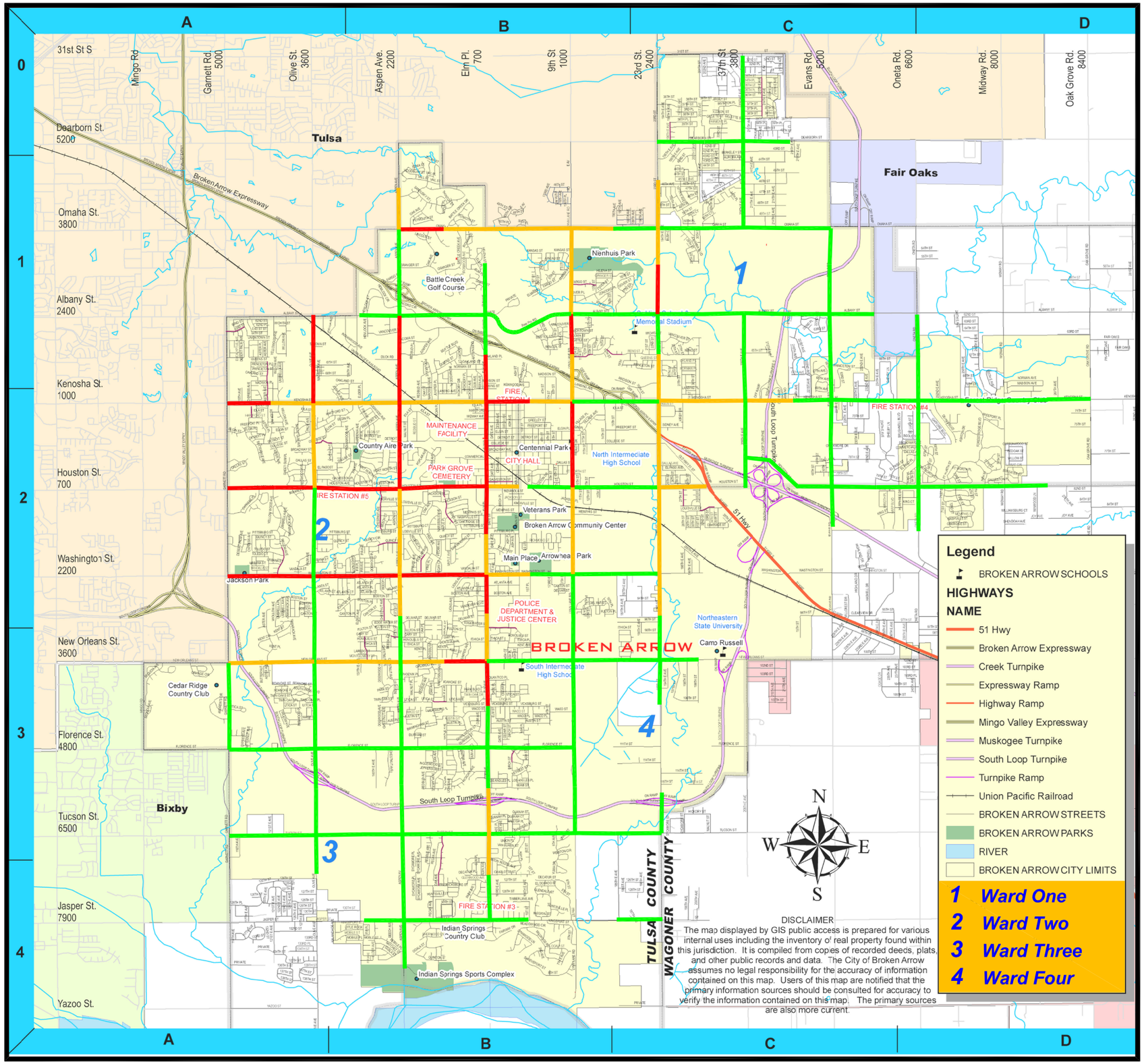

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MAP 7
YEAR 2015 ROADWAY LEVELS-OF-SERVICE

LEGEND

SEGMENT	LEVEL OF SERVICE
	A, B, & C (ACCEPTABLE)
	D & E (MARGINAL)
	F (UNSATISFACTORY)

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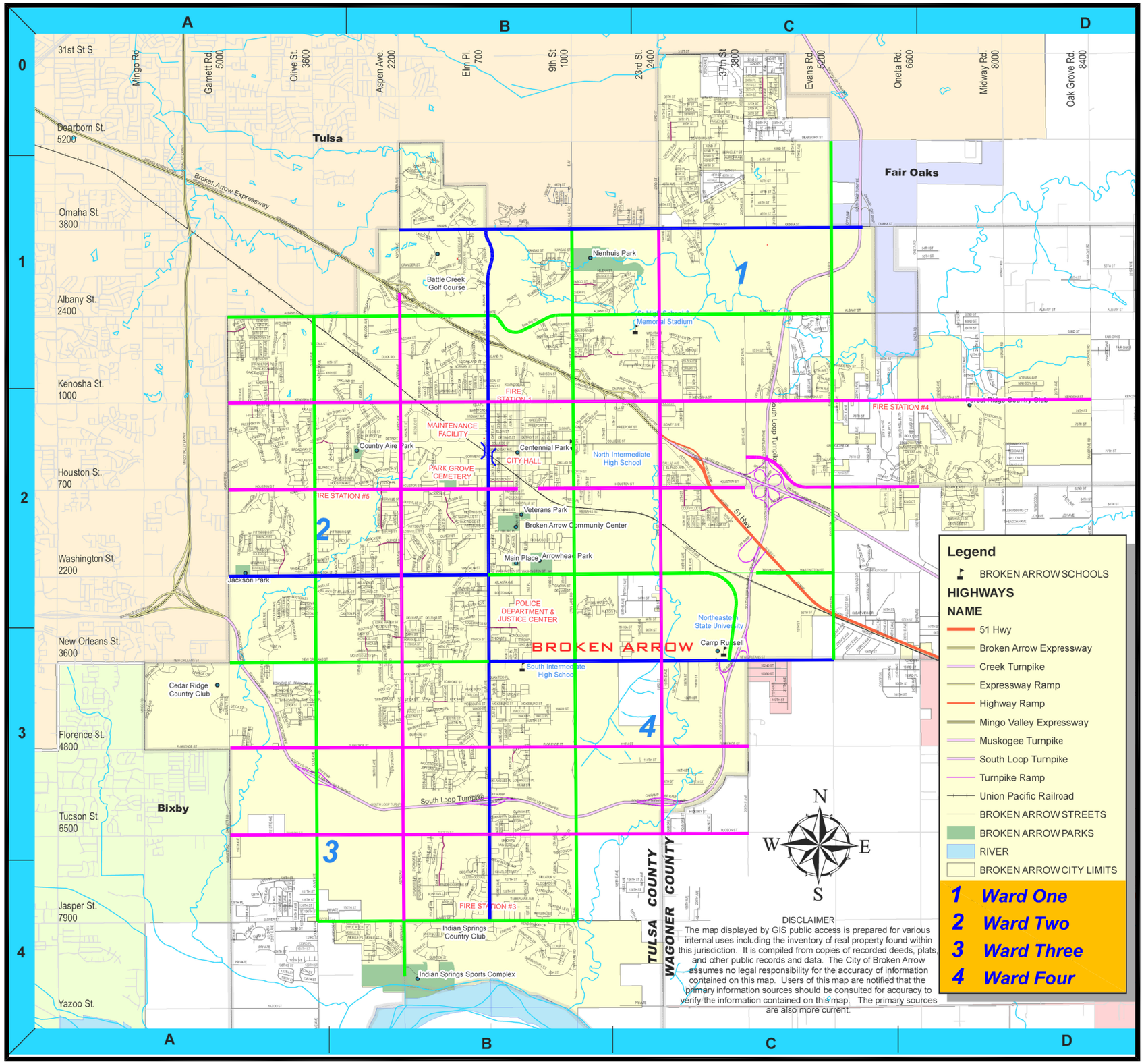

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MAP 8 RECOMMENDED ARTERIAL CLASSIFICATIONS

LEGEND

CORRIDOR

- PARKWAY
- TRANSITIONAL
- MULTI-USE

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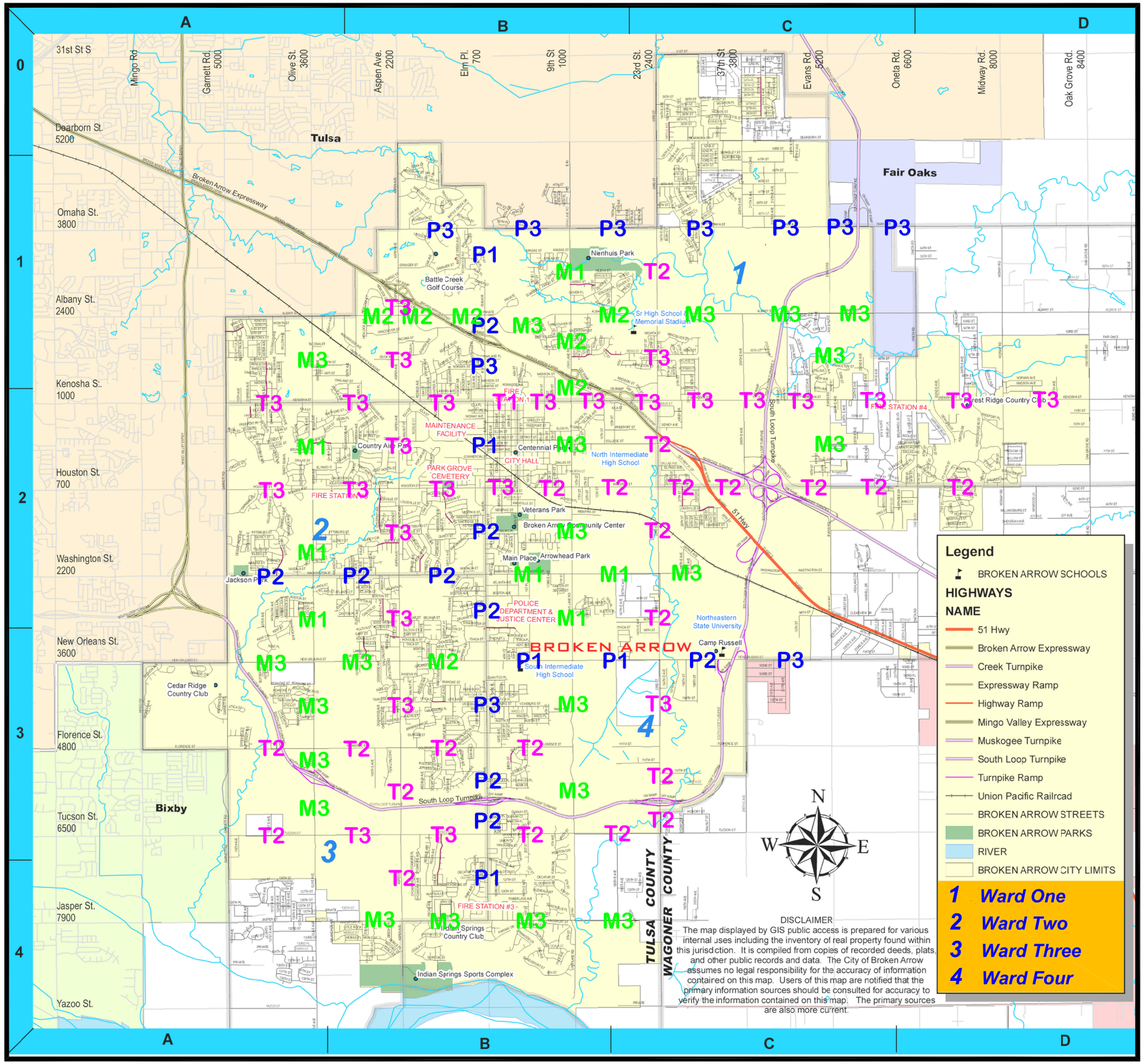

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MAP 9
TWO-WAY LEFT-TURN LANES/ MEDIAN ISLANDS

LEGEND

PARKWAY	PRIORITY
P1	HIGH
P2	MEDIUM
P3	LOW

MULTI-USE	PRIORITY
M1	HIGH
M2	MEDIUM
M3	LOW

TRANSITIONAL	PRIORITY
T1	HIGH
T2	MEDIUM
T3	LOW

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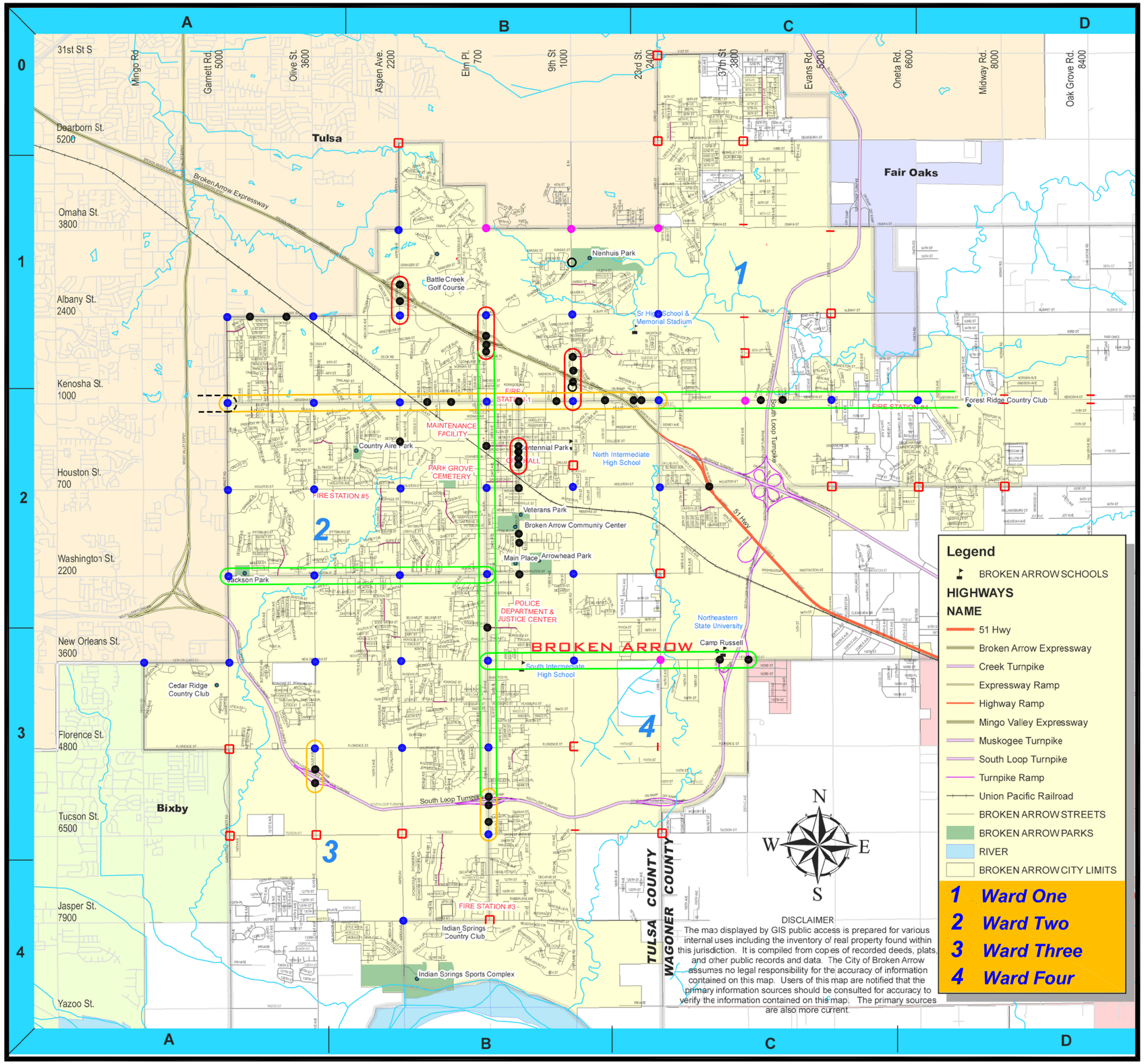

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2008 TRAFFIC STUDY & STREET IMPROVEMENTS EVALUATION

MAP 10 RECOMMENDED SIGNAL COORDINATION

LEGEND

CORRIDOR

- FIRST PRIORITY (1 YEAR)
- SECOND PRIORITY (2-3 YEARS)
- THIRD PRIORITY (3-5 YEARS)
- EXISTING COORDINATION

IINTERSECTION

- EXISTING ARTERIAL SIGNAL
- PROPOSED ARTERIAL SIGNAL
- EXISTING OFF-GRID SIGNAL
- PROPOSED OFF-GRID SIGNAL
- STOP-CONTROLLED (WITH STOP-CONTROLLED APPROACHES INDICATED)

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APPENDIX

Broken Arrow Traffic Study

Standard Roadway Capacities

Inventory ID	Roadway Type	Level-of-Service					
		A	B	C	D	E	F
2	2-lane arterial (undivided)	< 5,100	< 8,500	< 11,900	< 15,300	< 17,000	> 17,000
3	3-lane arterial (two-way left)	< 6,000	< 10,000	< 14,000	< 18,000	< 20,000	> 20,000
4	4-lane arterial (undivided)	< 10,200	< 17,000	< 23,800	< 30,600	< 34,000	> 34,000
not used	4-lane arterial (divided)	< 11,400	< 19,000	< 26,600	< 34,200	< 38,000	> 38,000
not used	4-lane parkway (undivided)	< 12,000	< 20,000	< 28,000	< 36,000	< 40,000	> 40,000
4d	4-lane parkway (divided)	< 13,200	< 22,000	< 30,800	< 39,600	< 44,000	> 44,000
5	5-lane arterial (two-way left)	< 10,800	< 18,000	< 25,200	< 32,400	< 36,000	> 36,000
6a	6-lane arterial (undivided)	< 15,300	< 25,500	< 35,700	< 45,900	< 51,000	> 51,000
6b	6-lane arterial (divided)	< 17,400	< 29,000	< 40,600	< 52,200	< 58,000	> 58,000
6c	6-lane parkway (divided)	< 18,000	< 30,000	< 42,000	< 54,000	< 60,000	> 60,000
7	7-lane arterial (two-way left)	< 18,100	< 30,200	< 42,200	< 54,300	< 60,300	> 60,300

Based on INCOG criteria for the Tulsa TMA as identified in the 2025 LRTP Update (with 7-lane capacities extrapolated)

Broken Arrow Traffic Study
Arterial Levels-of-Service

				Year 2007			Year 2010			Year 2015		
Arterial	**Block**	**Inventory ID**	**LOS C ADT**	**ADT**	**LOS**	**% of LOS C**	**ADT**	**LOS**	**% of LOS C**	**ADT**	**LOS**	**% of LOS C**
Dearborn	E of 23rd	2	11,900	6,447	B	54%	7,463	B	63%	9,525	C	80%
Dearborn	W of 37th	2	11,900	2,943	A	25%	3,407	A	29%	4,348	A	37%
Dearborn	E of 37th	2	11,900	1,318	A	11%	1,526	A	13%	1,947	A	16%
Omaha	E of Aspen	2	11,900	12,411	D	104%	14,367	D	121%	18,337	F	154%
Omaha	W of Elm	2	11,900	11,037	C	93%	12,777	D	107%	16,307	E	137%
Omaha	E of Elm	2	11,900	10,987	C	92%	12,719	D	107%	16,233	E	136%
Omaha	W of 9th	2	11,900	9,640	C	81%	11,160	C	94%	14,243	D	120%
Omaha	E of 9th	2	11,900	9,215	C	77%	10,668	C	90%	13,615	D	114%
Omaha	W of 23rd	2	11,900	7,124	B	60%	8,247	B	69%	10,525	C	88%
Omaha	E of 23rd	2	11,900	7,387	B	62%	8,551	C	72%	10,914	C	92%
Omaha	W of 37th	2	11,900	3,960	A	33%	4,584	A	39%	5,851	B	49%
Omaha	E of 37th	2	11,900	2,121	A	18%	2,455	A	21%	3,134	A	26%
Omaha	W of Evans	2	11,900	1,492	A	13%	1,727	A	15%	2,204	A	19%
Albany	W of Aspen	5	25,200	10,356	A	41%	11,988	B	48%	15,301	B	61%
Albany	E of Aspen	5	25,200	7,287	A	29%	8,436	A	33%	10,766	A	43%
Albany	W of Elm	5	25,200	7,329	A	29%	8,484	A	34%	10,828	B	43%
Albany	E of Elm	4d	30,800	7,899	A	26%	9,144	A	30%	11,670	A	38%
Albany	W of 9th	4d	30,800	7,999	A	26%	9,260	A	30%	11,818	A	38%
Albany	E of 9th	3	14,000	7,029	B	50%	8,137	B	58%	10,385	C	74%
Albany	W of 23rd	3	14,000	5,228	A	37%	6,052	B	43%	7,724	B	55%
Albany	E of 23rd	2	11,900	1,772	A	15%	2,051	A	17%	2,618	A	22%
Albany	W of 37th	2	11,900	1,161	A	10%	1,344	A	11%	1,715	A	14%
Albany	E of 37th	2	11,900	1,154	A	10%	1,336	A	11%	1,705	A	14%
Albany	W of Evans	2	11,900	657	A	6%	761	A	6%	971	A	8%
Albany	E of Evans	2	11,900	653	A	5%	756	A	6%	965	A	8%
Kenosha	E of Garnett	5	25,200	29,280	D	116%	33,895	E	135%	43,260	F	172%
Kenosha	W of Olive	5	25,200	22,924	C	91%	26,537	D	105%	33,869	E	134%
Kenosha	E of Olive	5	25,200	20,434	C	81%	23,655	C	94%	30,190	D	120%
Kenosha	W of Aspen	5	25,200	19,666	C	78%	22,766	C	90%	29,056	D	115%
Kenosha	E of Aspen	5	25,200	20,064	C	80%	23,227	C	92%	29,644	D	118%
Kenosha	W of Elm	5	25,200	22,536	C	89%	26,088	D	104%	33,296	E	132%
Kenosha	E of Elm	4	23,800	25,180	D	106%	29,149	D	122%	37,202	F	156%
Kenosha	W of 9th	5	25,200	17,175	B	68%	19,882	C	79%	25,375	D	101%
Kenosha	E of 9th	7	43,000	19,166	B	45%	22,187	B	52%	28,317	B	66%
Kenosha	W of 23rd	7	43,000	27,266	B	63%	31,564	C	73%	40,284	C	94%
Kenosha	E of 23rd	4	23,800	16,816	B	71%	19,467	C	82%	24,845	D	104%

Arterial Levels-of-Service

				Year 2007			Year 2010			Year 2015		
Arterial	Block	Inventory ID	LOS C ADT	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C
Kenosha	W of 37th	4	23,800	16,788	B	71%	19,434	C	82%	24,804	D	104%
Kenosha	E of 37th	4	23,800	16,257	B	68%	18,820	C	79%	24,019	D	101%
Kenosha	W of Evans	4	23,800	16,002	B	67%	18,524	C	78%	23,642	C	99%
Kenosha	E of Evans	4	23,800	15,260	B	64%	17,665	C	74%	22,546	C	95%
Kenosha	W of Oneta	4	23,800	13,610	B	57%	15,755	B	66%	20,108	C	84%
Kenosha	E of Oneta	4	23,800	11,274	B	47%	13,051	B	55%	16,657	B	70%
Kenosha	W of Midway	4	23,800	8,468	A	36%	9,803	A	41%	12,511	B	53%
Kenosha	E of Midway	4	23,800	6,155	A	26%	7,125	A	30%	9,094	A	38%
Kenosha	W of Oak Grove	4	23,800	5,634	A	24%	6,522	A	27%	8,324	A	35%
Houston	E of Garnett	3	14,000	18,418	E	132%	21,321	F	152%	27,212	F	194%
Houston	W of Olive	3	14,000	16,096	D	115%	18,633	E	133%	23,781	F	170%
Houston	E of Olive	3	14,000	14,740	D	105%	17,063	D	122%	21,778	F	156%
Houston	W of Aspen	3	14,000	14,239	D	102%	16,483	D	118%	21,037	F	150%
Houston	E of Aspen	3	14,000	17,260	D	123%	19,981	E	143%	25,501	F	182%
Houston	W of Elm	3	14,000	16,276	D	116%	18,842	E	135%	24,047	F	172%
Houston	E of Elm	3	14,000	10,645	C	76%	12,323	C	88%	15,728	D	112%
Houston	W of 9th	2	11,900	5,133	B	43%	5,942	B	50%	7,584	B	64%
Houston	E of 9th	2	11,900	7,668	B	64%	8,877	C	75%	11,329	C	95%
Houston	W of 23rd	2	11,900	7,219	B	61%	8,357	B	70%	10,666	C	90%
Houston	E of 23rd	2	11,900	8,562	C	72%	9,912	C	83%	12,650	D	106%
Houston	E of 37th	2	11,900	4,230	A	36%	4,897	A	41%	6,250	B	53%
Houston	W of Evans	2	11,900	4,223	A	35%	4,889	A	41%	6,239	B	52%
Houston	E of Evans	2	11,900	4,000	A	34%	4,631	A	39%	5,910	B	50%
Houston	W of Oneta	2	11,900	3,064	A	26%	3,547	A	30%	4,527	A	38%
Houston	E of Oneta	2	11,900	3,147	A	26%	3,643	A	31%	4,650	A	39%
Houston	W of Midway	2	11,900	1,400	A	12%	1,621	A	14%	2,068	A	17%
Houston	E of Midway	2	11,900	706	A	6%	817	A	7%	1,043	A	9%
Washington	E of Garnett	3	14,000	17,755	D	127%	20,554	F	147%	26,232	F	187%
Washington	W of Olive	3	14,000	17,009	D	121%	19,690	E	141%	25,130	F	180%
Washington	E of Olive	3	14,000	16,620	D	119%	19,240	E	137%	24,555	F	175%
Washington	W of Aspen	3	14,000	16,214	D	116%	18,770	E	134%	23,955	F	171%
Washington	E of Aspen	3	14,000	19,725	E	141%	22,834	F	163%	29,143	F	208%
Washington	W of Elm	3	14,000	15,513	D	111%	17,958	D	128%	22,920	F	164%
Washington	E of Elm	3	14,000	12,561	C	90%	14,541	D	104%	18,558	E	133%
Washington	W of 9th	3	14,000	8,816	B	63%	10,206	C	73%	13,025	C	93%
Washington	E of 9th	2	11,900	5,055	A	42%	5,852	B	49%	7,469	B	63%
Washington	W of 23rd	2	11,900	4,400	A	37%	5,094	A	43%	6,501	B	55%

Arterial Levels-of-Service

				Year 2007			Year 2010			Year 2015		
Arterial	Block	Inventory ID	LOS C ADT	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C
New Orleans	E of Garnett	2	11,900	10,215	C	86%	11,825	C	99%	15,092	D	127%
New Orleans	W of Olive	2	11,900	8,342	B	70%	9,657	C	81%	12,325	D	104%
New Orleans	E of Olive	2	11,900	8,772	C	74%	10,155	C	85%	12,960	D	109%
New Orleans	W of Aspen	2	11,900	9,533	C	80%	11,036	C	93%	14,085	D	118%
New Orleans	E of Aspen	3	14,000	13,241	C	95%	15,328	D	109%	19,563	E	140%
New Orleans	W of Elm	3	14,000	15,602	D	111%	18,061	E	129%	23,051	F	165%
New Orleans	E of Elm	5	25,200	12,512	B	50%	14,484	B	57%	18,486	C	73%
New Orleans	W of 9th	5	25,200	5,750	A	23%	6,656	A	26%	8,495	A	34%
New Orleans	E of 9th	3	14,000	7,336	B	52%	8,492	B	61%	10,839	C	77%
New Orleans	W of 23rd	3	14,000	7,237	B	52%	8,378	B	60%	10,692	C	76%
New Orleans	E of 23rd	3	14,000	7,164	B	51%	8,293	B	59%	10,584	C	76%
Florence	E of Garnett	2	11,900	6,042	B	51%	6,994	B	59%	8,927	C	75%
Florence	W of Olive	2	11,900	5,598	B	47%	6,480	B	54%	8,271	B	70%
Florence	E of Olive	2	11,900	6,331	B	53%	7,329	B	62%	9,354	C	79%
Florence	W of Aspen	2	11,900	6,405	B	54%	7,415	B	62%	9,463	C	80%
Florence	E of Aspen	2	11,900	7,450	B	63%	8,624	C	72%	11,007	C	92%
Florence	W of Elm	2	11,900	7,350	B	62%	8,509	C	72%	10,859	C	91%
Florence	E of Elm	2	11,900	1,993	A	17%	2,307	A	19%	2,945	A	25%
Florence	W of 9th	2	11,900	2,846	A	24%	3,295	A	28%	4,205	A	35%
Tuscon	E of Garnett	2	11,900	3,210	A	27%	3,716	A	31%	4,743	A	40%
Tuscon	W of Olive	2	11,900	2,585	A	22%	2,992	A	25%	3,819	A	32%
Tuscon	E of Olive	2	11,900	4,205	A	35%	4,868	A	41%	6,213	B	52%
Tuscon	W of Aspen	2	11,900	3,474	A	29%	4,022	A	34%	5,133	B	43%
Tuscon	E of Aspen	2	11,900	5,217	B	44%	6,039	B	51%	7,708	B	65%
Tuscon	W of Elm	2	11,900	4,163	A	35%	4,819	A	40%	6,151	B	52%
Tuscon	E of Elm	2	11,900	6,339	B	53%	7,338	B	62%	9,366	C	79%
Tuscon	W of 9th	2	11,900	3,845	A	32%	4,451	A	37%	5,681	B	48%
Tuscon	E of 9th	2	11,900	2,862	A	24%	3,313	A	28%	4,228	A	36%
Tuscon	W of 23rd	2	11,900	2,528	A	21%	2,926	A	25%	3,735	A	31%
Jasper	W of Aspen	2	11,900	5,701	B	48%	6,600	B	55%	8,423	B	71%
Jasper	E of Aspen	2	11,900	6,203	B	52%	7,181	B	60%	9,165	C	77%
Jasper	W of Elm	2	11,900	6,266	B	53%	7,254	B	61%	9,258	C	78%
Jasper	E of Elm	2	11,900	7,691	B	65%	8,903	C	75%	11,363	C	95%
Jasper	W of 23rd	2	11,900	3,424	A	29%	3,964	A	33%	5,059	A	43%
Garnett	S of New Orleans	2	11,900	6,360	B	53%	7,362	B	62%	9,397	C	79%
Garnett	N of Florence	2	11,900	5,079	A	43%	5,880	B	49%	7,504	B	63%
Olive	S of Albany	2	11,900	12,124	D	102%	14,035	D	118%	17,913	F	151%

Arterial Levels-of-Service

				Year 2007			Year 2010			Year 2015		
Arterial	Block	Inventory ID	LOS C ADT	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C
Olive	N of Kenosha	2	11,900	11,655	C	98%	13,492	D	113%	17,220	F	145%
Olive	S of Kenosha	3	14,000	12,266	C	88%	14,199	D	101%	18,122	E	129%
Olive	N of Houston	3	14,000	10,320	C	74%	11,947	C	85%	15,247	D	109%
Olive	S of Houston	3	14,000	8,335	B	60%	9,649	B	69%	12,315	C	88%
Olive	N of Washington	3	14,000	7,179	B	51%	8,311	B	59%	10,607	C	76%
Olive	S of Washington	2	11,900	7,472	B	63%	8,650	C	73%	11,040	C	93%
Olive	N of New Orleans	2	11,900	5,083	A	43%	5,884	B	49%	7,510	B	63%
Olive	S of New Orleans	2	11,900	5,275	B	44%	6,106	B	51%	7,794	B	65%
Olive	N of Florence	2	11,900	4,564	A	38%	5,283	B	44%	6,743	B	57%
Olive	S of Florence	2	11,900	5,141	B	43%	5,951	B	50%	7,596	B	64%
Olive	N of Tuscson	2	11,900	6,038	B	51%	6,990	B	59%	8,921	C	75%
Olive	S of Tuscon	2	11,900	4,821	A	41%	5,581	B	47%	7,123	B	60%
Aspen	N of Omaha	2	11,900	11,417	C	96%	13,217	D	111%	16,868	E	142%
Aspen	S of Omaha	5	25,200	14,409	B	57%	16,680	B	66%	21,289	C	84%
Aspen	N of Albany	7	43,000	17,401	A	40%	20,144	B	47%	25,709	B	60%
Aspen	S of Albany	5	25,200	30,184	D	120%	34,942	E	139%	44,596	F	177%
Aspen	N of Kenosha	5	25,200	31,034	D	123%	35,926	E	143%	45,851	F	182%
Aspen	S of Kenosha	5	25,200	32,365	D	128%	37,467	F	149%	47,818	F	190%
Aspen	N of Houston	5	25,200	26,324	D	104%	30,473	D	121%	38,893	F	154%
Aspen	S of Houston	5	25,200	23,298	C	92%	26,970	D	107%	34,422	E	137%
Aspen	N of Washington	5	25,200	20,684	C	82%	23,944	C	95%	30,560	D	121%
Aspen	S of Washington	5	25,200	19,472	C	77%	22,541	C	89%	28,769	D	114%
Aspen	N of New Orleans	5	25,200	13,374	B	53%	15,482	B	61%	19,759	C	78%
Aspen	S of New Orleans	5	25,200	10,759	A	43%	12,455	B	49%	15,896	B	63%
Aspen	N of Florence	5	25,200	8,249	A	33%	9,549	A	38%	12,188	B	48%
Aspen	S of Florence	2	11,900	5,238	B	44%	6,064	B	51%	7,739	B	65%
Aspen	N of Tuscson	2	11,900	5,189	B	44%	6,007	B	50%	7,667	B	64%
Aspen	S of Tuscon	2	11,900	3,698	A	31%	4,281	A	36%	5,464	B	46%
Aspen	N of Jasper	2	11,900	4,134	A	35%	4,786	A	40%	6,108	B	51%
Aspen	S of Jasper	4d	30,800	2,708	A	9%	3,135	A	10%	4,001	A	13%
Elm	N of Albany	5	25,200	2,858	A	11%	3,308	A	13%	4,223	A	17%
Elm	S of Albany	5	25,200	9,883	A	39%	11,441	B	45%	14,602	B	58%
Elm	N of Kenosha	4	23,800	25,908	D	109%	29,992	D	126%	38,278	F	161%
Elm	S of Kenosha	4	23,800	26,557	D	112%	30,743	E	129%	39,237	F	165%
Elm	N of Houston	4	23,800	25,272	D	106%	29,255	D	123%	37,338	F	157%
Elm	S of Houston	5	25,200	24,644	C	98%	28,529	D	113%	36,410	F	144%
Elm	N of Washington	5	25,200	20,528	C	81%	23,764	C	94%	30,329	D	120%

Arterial Levels-of-Service

				Year 2007			Year 2010			Year 2015		
Arterial	Block	Inventory ID	LOS C ADT	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C	ADT	LOS	% of LOS C
Elm	S of Washington	5	25,200	25,402	D	101%	29,406	D	117%	37,530	F	149%
Elm	N of New Orleans	5	25,200	20,000	C	79%	23,153	C	92%	29,549	D	117%
Elm	S of New Orleans	4	23,800	23,298	C	98%	26,970	D	113%	34,422	F	145%
Elm	N of Florence	4	23,800	15,980	B	67%	18,499	C	78%	23,610	C	99%
Elm	S of Florence	5	25,200	17,016	B	68%	19,698	C	78%	25,140	C	100%
Elm	N of Tuscson	5	25,200	19,137	C	76%	22,153	C	88%	28,274	D	112%
Elm	S of Tuscon	3	14,000	12,200	C	87%	14,123	D	101%	18,025	E	129%
Elm	N of Jasper	3	14,000	8,963	B	64%	10,376	C	74%	13,242	C	95%
9th	S of Omaha	3	14,000	9,897	B	71%	11,457	C	82%	14,622	D	104%
9th	N of Albany	3	14,000	13,484	C	96%	15,609	D	111%	19,922	E	142%
9th	S of Albany	3	14,000	14,081	D	101%	16,301	D	116%	20,804	F	149%
9th	N of Kenosha	5	25,200	21,390	C	85%	24,762	C	98%	31,603	D	125%
9th	S of Kenosha	2	11,900	14,975	D	126%	17,335	F	146%	22,125	F	186%
9th	N of Houston	2	11,900	12,060	D	101%	13,961	D	117%	17,818	F	150%
9th	S of Houston	2	11,900	10,002	C	84%	11,579	C	97%	14,778	D	124%
9th	N of Washington	2	11,900	8,122	B	68%	9,402	C	79%	12,000	D	101%
9th	S of Washington	2	11,900	6,461	B	54%	7,479	B	63%	9,546	C	80%
9th	N of New Orleans	2	11,900	7,749	B	65%	8,970	C	75%	11,449	C	96%
9th	S of New Orleans	2	11,900	4,811	A	40%	5,569	B	47%	7,108	B	60%
9th	N of Florence	2	11,900	4,035	A	34%	4,671	A	39%	5,962	B	50%
9th	S of Florence	2	11,900	2,262	A	19%	2,619	A	22%	3,342	A	28%
9th	N of Tuscson	2	11,900	2,867	A	24%	3,319	A	28%	4,236	A	36%
23rd	N of Omaha	2	11,900	10,101	C	85%	11,693	C	98%	14,924	D	125%
23rd	S of Omaha	2	11,900	11,383	C	96%	13,177	D	111%	16,818	E	141%
23rd	N of Albany	2	11,900	12,282	D	103%	14,218	D	119%	18,146	F	152%
23rd	S of Albany	5	25,200	13,652	B	54%	15,804	B	63%	20,170	C	80%
23rd	N of Kenosha	5	25,200	17,683	B	70%	20,470	C	81%	26,126	D	104%
23rd	S of Kenosha	2	11,900	11,046	C	93%	12,787	D	107%	16,320	E	137%
23rd	N of Houston	2	11,900	10,018	C	84%	11,597	C	97%	14,801	D	124%
23rd	S of Houston	2	11,900	8,197	B	69%	9,489	C	80%	12,111	D	102%
23rd	N of Washington	2	11,900	8,301	B	70%	9,609	C	81%	12,264	D	103%
23rd	S of Washington	2	11,900	8,666	C	73%	10,032	C	84%	12,804	D	108%
23rd	N of New Orleans	2	11,900	6,611	B	56%	7,653	B	64%	9,767	C	82%
23rd	S of New Orleans	5	25,200	4,021	A	16%	4,655	A	18%	5,941	A	24%
23rd	N of Tuscson	2	11,900	5,754	B	48%	6,661	B	56%	8,501	C	71%
37th	S of 31st	2	11,900	2,585	A	22%	2,992	A	25%	3,819	A	32%
37th	N of Dearborn	2	11,900	2,927	A	25%	3,388	A	28%	4,325	A	36%

Arterial Levels-of-Service

				Year 2007			Year 2010			Year 2015		
Arterial	**Block**	**Inventory ID**	**LOS C ADT**	**ADT**	**LOS**	**% of LOS C**	**ADT**	**LOS**	**% of LOS C**	**ADT**	**LOS**	**% of LOS C**
37th	S of Dearborn	2	11,900	2,239	A	19%	2,592	A	22%	3,308	A	28%
37th	N of Omaha	2	11,900	3,007	A	25%	3,481	A	29%	4,443	A	37%
37th	S of Albany	2	11,900	234	A	2%	271	A	2%	346	A	3%
37th	N of Kenosha	2	11,900	391	A	3%	453	A	4%	578	A	5%
37th	S of Kenosha	2	11,900	353	A	3%	409	A	3%	522	A	4%
37th	N of Houston	2	11,900	345	A	3%	399	A	3%	510	A	4%
37th	S of Houston	2	11,900	4,384	A	37%	5,075	A	43%	6,477	B	54%
Evans	S of Omaha	2	11,900	167	A	1%	193	A	2%	247	A	2%
Evans	N of Albany	2	11,900	168	A	1%	194	A	2%	248	A	2%
Evans	S of Albany	2	11,900	45	A	0%	52	A	0%	66	A	1%
Evans	N of Kenosha	2	11,900	578	A	5%	669	A	6%	854	A	7%
Evans	S of Kenosha	2	11,900	1,516	A	13%	1,755	A	15%	2,240	A	19%
Evans	N of Houston	2	11,900	1,312	A	11%	1,519	A	13%	1,938	A	16%
Evans	S of Houston	2	11,900	438	A	4%	507	A	4%	647	A	5%
Oneta	S of Albany	2	11,900	1,320	A	11%	1,528	A	13%	1,950	A	16%
Oneta	N of Kenosha	2	11,900	2,287	A	19%	2,647	A	22%	3,379	A	28%
Oneta	S of Kenosha	2	11,900	2,290	A	19%	2,651	A	22%	3,383	A	28%
Oneta	N of Houston	2	11,900	1,726	A	15%	1,998	A	17%	2,550	A	21%
Oneta	S of Houston	2	11,900	1,811	A	15%	2,096	A	18%	2,676	A	22%

Broken Arrow Traffic Study

Intersection Levels-of-Service Table

Intersection				AM				PM			
				2010		2015		2010		2015	
#	North/South Street	East/West Street	Control	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
1	Olive	Kenosha	Signal	100.5	F	167.1	F	434.6	F	704.7	F
2	Olive	Houston	Signal	96.1	F	109.6	F	143.2	F	167.7	F
3	Olive	Washington	Signal	62.3	E	70.4	E	95.7	F	114.8	F
4	Olive	New Orleans	Signal	26.2	C	36.0	D	46.3	D	72.2	E
5	Olive	Florence	Signal	39.9	D	45.7	D	38.5	D	40.9	D
6	Olive	Tucson	Stop	23.1	C	82.9	F	16.8	C	48.6	E
7	Aspen Ave.	Albany	Signal	43.4	D	48.7	D	77.5	E	90.2	F
8	Aspen Ave.	Kenosha	Signal	79.2	E	163.5	F	51.3	D	67.2	E
9	Aspen Ave.	Houston	Signal	45.0	D	56.1	E	26.5	C	27.7	C
10	Aspen Ave.	Washington	Signal	45.9	D	70.9	E	80.4	F	134.7	F
11	Aspen Ave.	New Orleans	Signal	33.0	C	37.0	D	37.6	D	44.3	D
12	Aspen Ave.	Florence	Signal	16.6	B	22.9	C	46.7	D	109.2	F
13	Aspen Ave.	Tucson	Stop	10.7	B	11.6	B	58.6	F	91.7	F
14	Aspen Ave.	Jasper	Signal	28.9	C	31.8	C	32.8	C	39.7	D
15	Elm	Albany	Signal	21.1	C	41.9	D	35.8	D	118.6	F
16	Elm	Kenosha	Signal	22.2	C	23.4	C	30.0	C	46.8	D
17	Elm	Houston	Signal	54.2	D	268.8	F	88.8	F	399.0	F
18	Elm	Washington	Signal	106.2	F	579.3	F	158.8	F	794.4	F
19	Elm	New Orleans	Signal	58.2	E	116.5	F	259.5	F	1180.1	F
20	Elm	Florence	Signal	38.4	D	42.7	D	45.2	D	60.3	E
21	Elm	Tucson	Signal	39.5	D	48.7	D	37.5	D	47.0	D
22	Elm	Jasper	Stop	11.2	B	11.4	B	13.5	B	15.1	C
23	9th	Albany	Signal	72.0	E	263.7	F	73.5	E	331.1	F
24	9th	Kenosha	Signal	61.4	E	147.2	F	73.8	F	222.6	F
25	9th	Houston	Signal	198.8	F	289.9	F	64.1	E	87.9	F
26	9th	Washington	Signal	19.9	B	50.0	D	32.1	C	90.5	F
27	9th	New Orleans	Signal	108.3	F	301.1	F	32.9	C	256.8	F
28	9th	Florence	Stop	9.3	A	11.9	B	8.8	A	11.8	B
29	23rd	Omaha	Signal	16.2	B	34.4	C	19.5	B	48.2	D
30	23rd	Albany	Signal	64.2	E	124.1	F	63.2	E	212.1	F
31	23rd	Kenosha	Signal	79.4	E	105.2	F	58.6	E	82.2	F
32	23rd	Houston	Signal	58.7	E	65.2	E	53.8	D	60.2	E
33	23rd	Washington	Stop	17.9	B	52.7	D	10.3	B	32.9	C
34	23rd	New Orleans	Signal	29.4	C	52.8	D	16.0	B	31.5	C
35	37th	Dearborn	Stop	8.4	A	11.7	B	9.6	A	11.5	B
37	37th	Kenosha	Stop	0.9	A	1.9	A	1.4	A	7.4	A
38	Evans	Albany	Stop	7.1	A	7.2	A	7.1	A	7.2	A
39	Evans	Kenosha	Signal	21.7	C	28.0	C	21.3	C	22.6	C
40	Evans	Houston	Stop	9.6	A	27.2	D	12.2	B	212.8	F
41	Oneta	Kenosha	Signal	23.9	C	30.1	C	24.5	C	29.7	C
42	Midway	Kenosha	Stop	15.2	C	117.9	F	14.4	B	1293.6	F