

**ELMWOOD ESTATES AND ARROWWOOD ESTATES
FLOOD MITIGATION REPORT**

BROKEN ARROW, OKLAHOMA

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7/26/17



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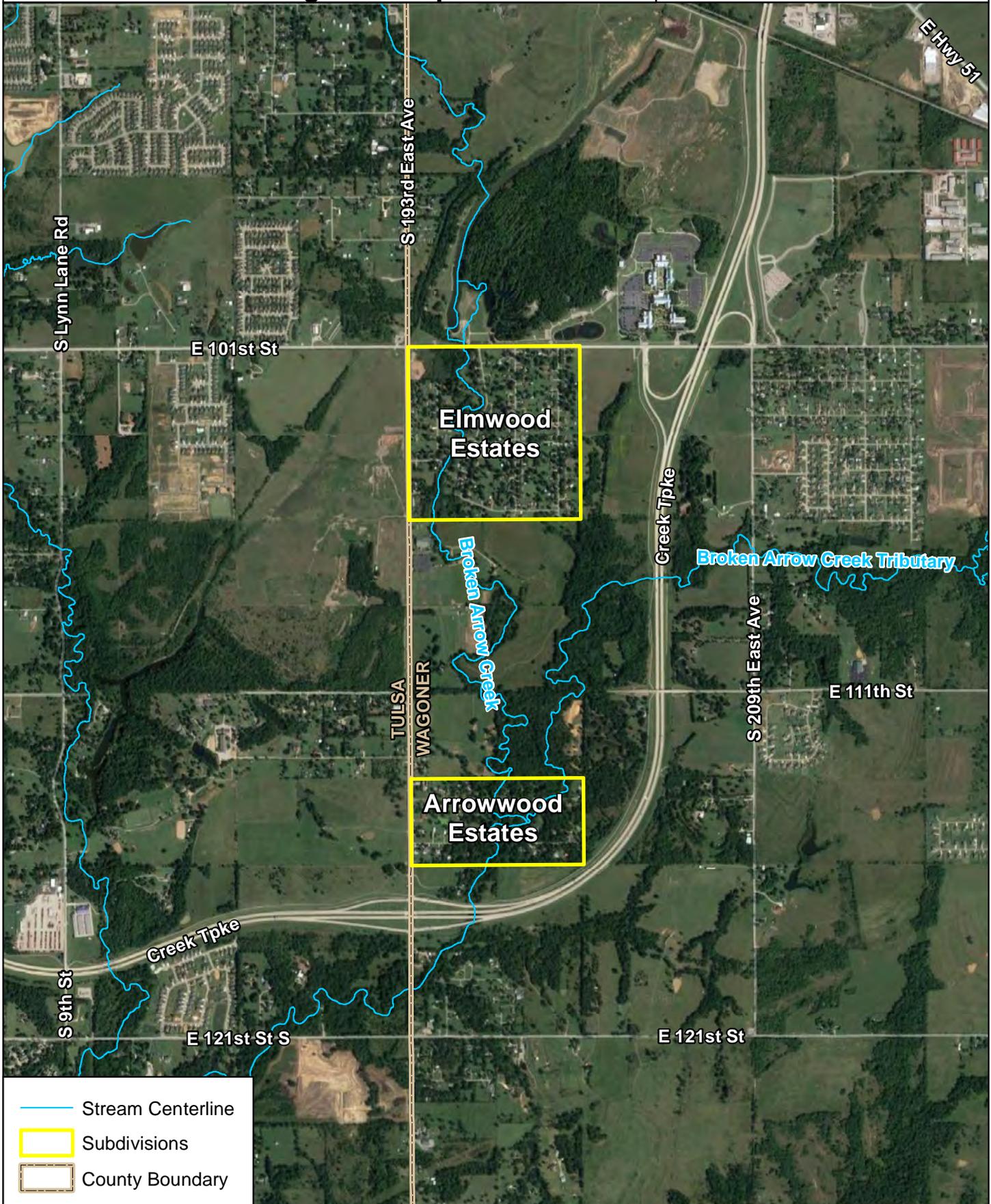
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Section 1. BACKGROUND

In August 2016, the City of Broken Arrow contracted the services of Meshek & Associates, LLC to perform flood mitigation analyses for the Elmwood Estates and Arrowwood Estates subdivisions in the Broken Arrow Creek drainage basin. The purpose of this project is to develop a Flood Mitigation Report that details the analyses performed and presents alternatives to mitigate flooding and drainage issues in the two subdivisions containing the Broken Arrow Creek floodplain. This study is focused mainly on two subdivisions – Elmwood Estates and Arrowwood Estates - bound between E 101st Street and the Creek Turnpike on the north and south side and the county line and Creek Turnpike on west and east. Elmwood Estates is just south of E. 101st Street and Arrowwood Estates is at E. 114th Street. **FIGURE 1-1** shows the area studied in detail.

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Section 2. ANALYSIS

Hydrologic and hydraulic modeling of Broken Arrow Creek and its Tributary basins were performed using HEC-HMS (Version 3.5), HEC-GeoRAS and HEC-RAS (Version 4.1.0), computer programs developed by US Army Corps of Engineers. The existing condition hydrology and hydraulic models for Broken Arrow Creek, developed by Utley and Associates in 2012 to update the FEMA floodplains, were used for this analysis. The base terrain data was developed from an aerial LIDAR survey performed for this project in 2011. No significant changes have occurred in the basin since then and thus the models reflect the actual existing conditions.

2.1 Hydrologic Analysis

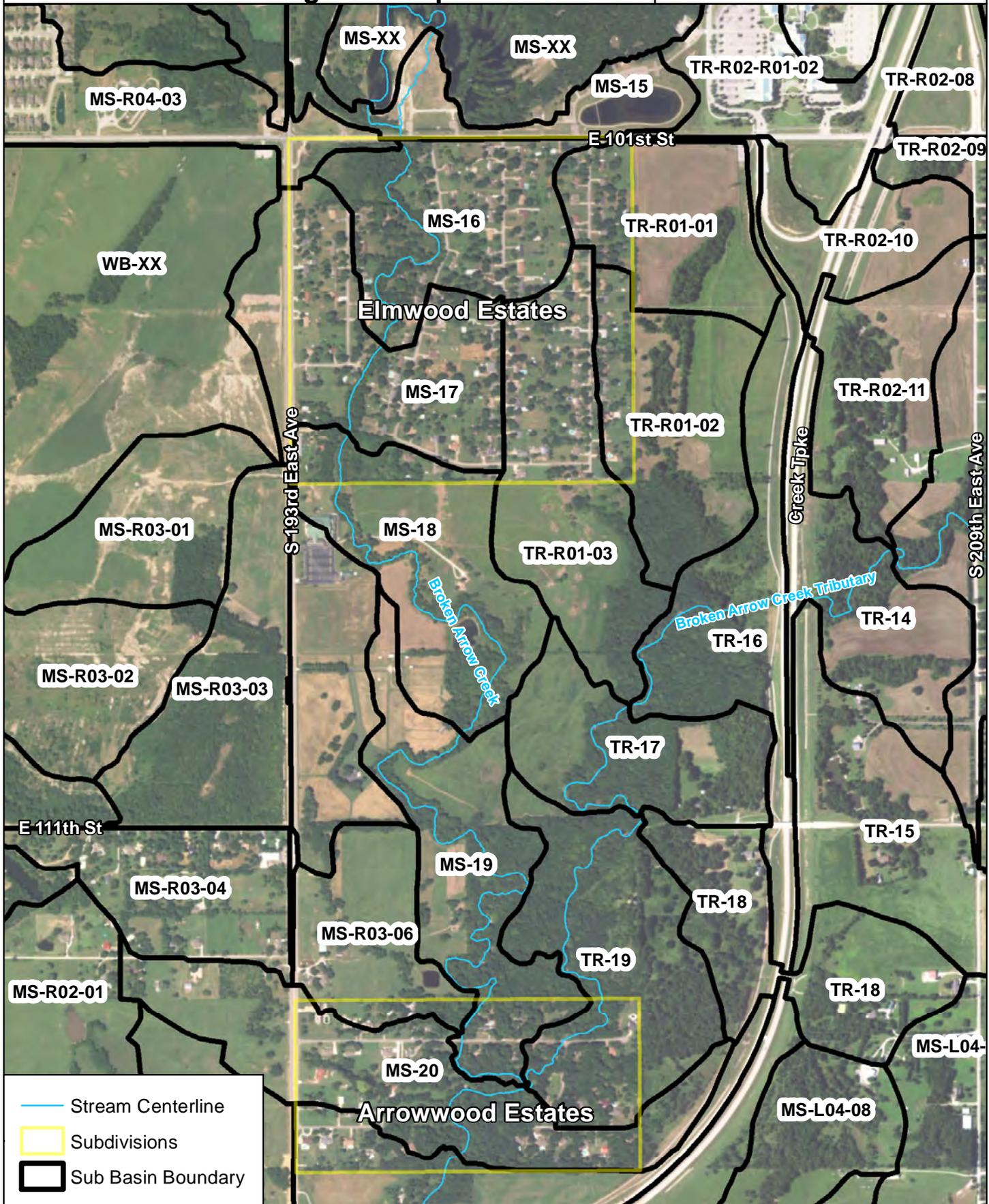
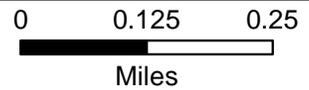
Hydrologic analysis was performed to determine stream flow at various points of interest within the Broken Arrow Creek basin. Flows have been determined for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year and 500-year recurrence interval rainfall events. The rainfall data for this study is taken from the U.S. Geologic Survey (USGS) publication "Depth-Duration Frequency of Precipitation for Oklahoma" (Water-Resources Investigations Report 99-3232). The USGS report has rainfall values for 1-day duration was chosen. The Storm Distribution, Abstraction Calculations, and Hydrograph Transform Method are taken from NRCS publications. The Storm Distribution used is the SCS Type II. The Abstraction Calculations are based on the NRCS (SCS) Curve Number methodology. The Hydrograph Transform is the NRCS (SCS) Dimensionless Unit Hydrograph, which is based on the single parameter Basin Lag. The curve numbers for each sub-basin are calculated using an area-weighted average based on the individual land uses and the hydrologic soil groups present in the basin. The hydrologic soil groups were determined from GIS data downloaded from the USDA Web Soil Survey (WSS). The land use data was developed based on inspection of the aerial photography obtained in 2011. The basin lag parameter is calculated as 60 percent of the basin time of concentration. The assumed average velocity for natural streams is 5 feet per second. The assumed average velocity for concrete channels (including storm sewers) is 8 feet per second. The routing reach calculations are based on the Modified Puls Method. The method is based on reach storage data (discharge / storage paired data) that is calculated from a hydraulic model for the reach. In order to generate conservative storage values, the hydraulic model used to calculate the reach storage contains open channel analysis only (all structures are removed). The final reach storage values are the result of an iterative solution of the hydrologic and hydraulic models. **FIGURE 2-1** shows the sub basins in the studied area. The hydrologic coefficients used in this analysis is included in **APPENDIX 2-A** and the HEC-HMS connectivity and the existing flow rates are included in **APPENDIX 2-B. TABLE 2-1** below gives the 24-hour rainfall depths used in the hydrologic analyses.

Table 2-1 Total Rainfall Depths for City of Broken Arrow, Oklahoma

Frequency (Return Period)	24-Hour Rainfall Depth (inches)
2-year	3.6
5-year	4.9
10-year	5.8
25-year	7.0
50-year	7.8
100-year	8.8
500-year	11.2

Table 2-1 Source: U.S. Weather Bureau Technical Paper No. 40 and Hydro 35

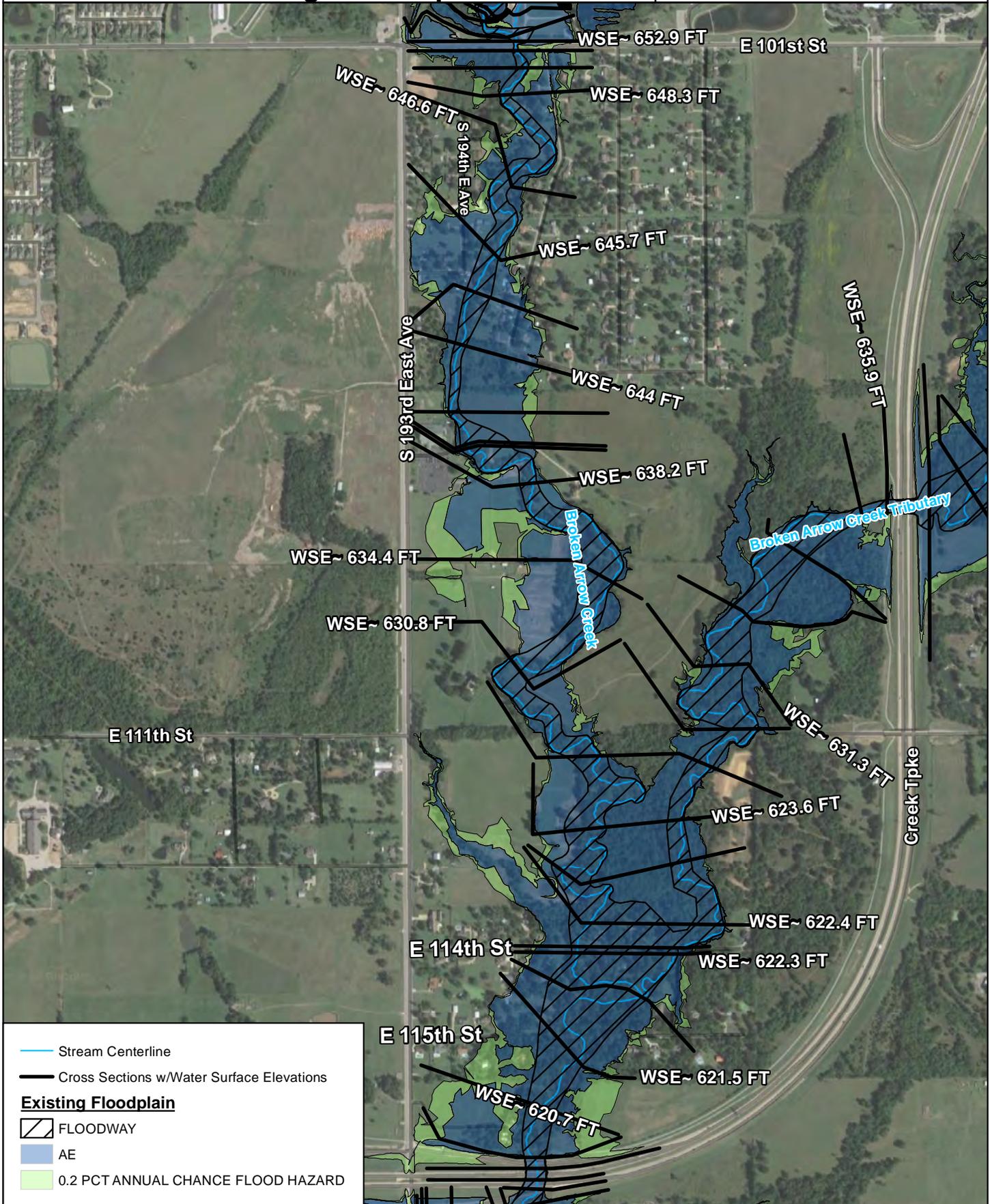
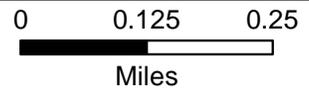
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2.2 Hydraulic Analysis

Hydraulic analysis has been performed to determine the flood elevations for the designated study reaches. Flood profiles have been determined for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year and 500-year recurrence interval discharges calculated by the hydrologic analysis. In addition, floodways have been calculated for the existing conditions based on FEMA requirements. The hydraulic modeling for the study employs the U.S. Army Corps of Engineers River Analysis System HEC-RAS version 4.1. The input requirements of the model are cross section data, roughness data, structure data and boundary conditions. The cross section and roughness data has been extracted using the GIS based tools developed by the Corps of Engineers (HEC-GeoRAS). The base terrain data was developed from an aerial LIDAR survey, performed in, for the detailed study areas. The model uses Manning's Roughness coefficients to compute friction losses. The Manning's "N" values were determined from the aerial photos taken during the LIDAR survey based on visible land cover. The structure data has been developed from on-site surveys. The starting water surface elevation boundary condition uses the normal depth option in HEC-RAS. The analysis includes floodway calculations for existing conditions on all the designated streams, based on FEMA requirements for flood insurance studies. **FIGURE 2-2** shows the stream alignments, existing floodplain and floodway extents, and water surface elevations near and through the project area.

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2.3 Problem Areas

Elmwood Estates subdivision is in the Broken Arrow Creek mainstem basin. Arrowwood Estates subdivision is situated at the confluence of Broken Arrow Creek Tributary and Broken Arrow Creek mainstem. Broken Arrow Creek mainstem has approximately 2010 acres of drainage area at this location and Broken Arrow Creek Tributary drains approximately 3710 acres at this confluence location. The floodplain is wide near this confluence. Several houses in both these subdivisions are in the 100-year floodplain. Several homeowners in this area have contacted the City of Broken Arrow about flooding concerns in previous years.

Two public meetings were held, on October 24, 2016 for Arrowwood Estates subdivision and on November 3, 2016 for Elmwood Estates subdivision, to identify the local problem areas and individual flooding issues in the two neighborhoods. Approximately 50 people showed up for the meetings and the city received 14 comment sheets. The data gathered from this public meeting was used to determine the problem areas to focus the analysis on these areas and develop alternatives. Some of the comments received mention individual flooding issues while most of them mention general issues in the subdivision and stream bank erosion. The information from the comments received are briefed below and the locations of these problem areas are given in **FIGURE 2-3**.

2.3.1 Problem Area 1: East 114th Street in Arrowwood Estates

Problem Area 1 is located in Arrowwood Estates subdivision. Arrowwood Estates is at the confluence of Broken Arrow Creek Tributary with the Mainstem. Houses are built along the sides of East 114th Street and East 115th Street and these roads are connected with South 199th East Avenue. In existing condition, the 1% Annual Chance (100-year) storm peak flow rate at the confluence is approximately 9015 cfs. The peak flow rate from Broken Arrow Creek Tributary near this confluence is 6798 cfs and the mainstem has a peak flow of 3640 cfs.

East 114th Street serves as the only access road to all houses in Arrowwood Estates. This street crosses both the Broken Arrow Creek mainstem and its tributary. In existing conditions, this road overtops from storm events as low as 50% Annual Chance (2-year) storm and blocks the access to several houses in this subdivision. The existing structure on Broken Arrow Creek mainstem is a 12'X8' RCB and on Broken Arrow Creek Tributary a 11'X6.5' RCB. There is significant bank erosion near these culverts. Also, there is a 30" RCP between these two boxes. Six properties on this street are built within a 100-year floodplain and of which 2 properties are repetitive loss structures per the Federal Emergency Management Agency (FEMA) insurance claim data.

2.3.2 Problem Area 2: Elmwood Estates

Problem Area 2 is located in Elmwood Estates on the Broken Arrow Creek mainstem. The subdivision starts to the south of East 101st Street and extends south to East 106th Street.

Several houses in this subdivision are in the 100-year floodplain and there is one property that has reported multiple flood insurance claims but is not on the current repetitive loss list. City of Broken Arrow is coordinating with FEMA to determine its status.

2.3.3 Problem Area 3: 19310 East 114th Street South

This location is outside of the 100-year floodplain of Broken Arrow Creek and is a localized drainage issue in Arrowwood Estates. There is a 10" steel pipe that crosses 114th Street, near the entrance of Arrowwood Estates, that drains to the front yard of this property. The yard is graded to flow west and then drain south into the creek behind the house. During heavy rain, the pipe gets clogged and water starts to pond on the north side of the road and eventually overtops the road. This causes a nuisance situation in the yards and the road as well as deteriorates the road.

2.3.4 Problem Area 4: 19769 East 114th Street South

This location is in Arrowwood Estates between Broken Arrow Creek mainstem and Broken Arrow Creek Tributary near its confluence on the north side of East 114th Street South. The owner of this property is concerned about safety hazards caused by the overflow water from Broken Arrow Creek Tributary which flows west through the street to make its way to a 30" RCP that drains across 114th Street between the creeks. This 30" RCP is located on the west side of this property. The ditch along the road is very overgrown and not maintained.

2.3.5 Problem Area 5: 19825 East 114th Street South

This location is in Arrowwood Estates and is situated in between Broken Arrow Creek mainstem and Broken Arrow Creek Tributary near its confluence on the north side of East 114th Street South. The owner of this property recommends improving the culverts on East 114th Street to improve the water flow through the structures. This house is built approximately 4 feet above the natural ground level and has a low area around the house.

2.3.6 Problem Area 6: 19825 East 115th Street South

This location is in the Arrowwood Estates subdivision. The resident says that this house was never flooded but it is shown on the floodplain. They also requested to clean the creek and take appropriate measures to have better flow through culverts under East 114th Street South.

2.3.7 Problem Area 7: 20024 & 20073 East 114th Street South

Both these locations are in Arrowwood Estates and their comments mention the erosion of stream banks on the Broken Arrow Creek Tributary at East 114th Street South crossing. The creek flows southwest to the culvert and has to make a ninety degree turn to go through the culvert. This structure is located close to the intersection of East 114th Street South and South 199th East Avenue. There is some major erosion on the sides of South 199th East Avenue where a cross drain is provided to drain the area to the west of this road. The water that

discharges on the west side of South 199th East Avenue has caused erosion at this location. The photographs below show the streambank erosion near this intersection.



2.3.8 Problem Area 8: 10407 South 194th East Avenue

This location is in the Elmwood Estates subdivision and is located on the east side of South 194th East Avenue near its intersection with East 105th Street South. There is a 24" RCP that drains across South 194th East Avenue and discharges into the north side of this property. This pipe drains approximately 17 acres. The downstream side of this pipe is not graded properly to

allow the water flow into Broken Arrow Creek. The water ponds near the downstream side of this pipe and floods the yard.

2.3.9 Problem Area 9: 10313 South 193rd East Avenue

This location is in the Elmwood Estates subdivision and is located on the east side of South 193rd East Avenue. There has been water in the garage during flood events as well as a lot of water in the back yard. Per the contour data from 2011, most of the houses between South 193rd East Avenue and South 194th East Avenue have their backyards draining south. This flow then turns southeast right at the backyard of this property before it gets into the 24" RCP under South 194th East Avenue. Approximately 8 acres of land drain to this location.

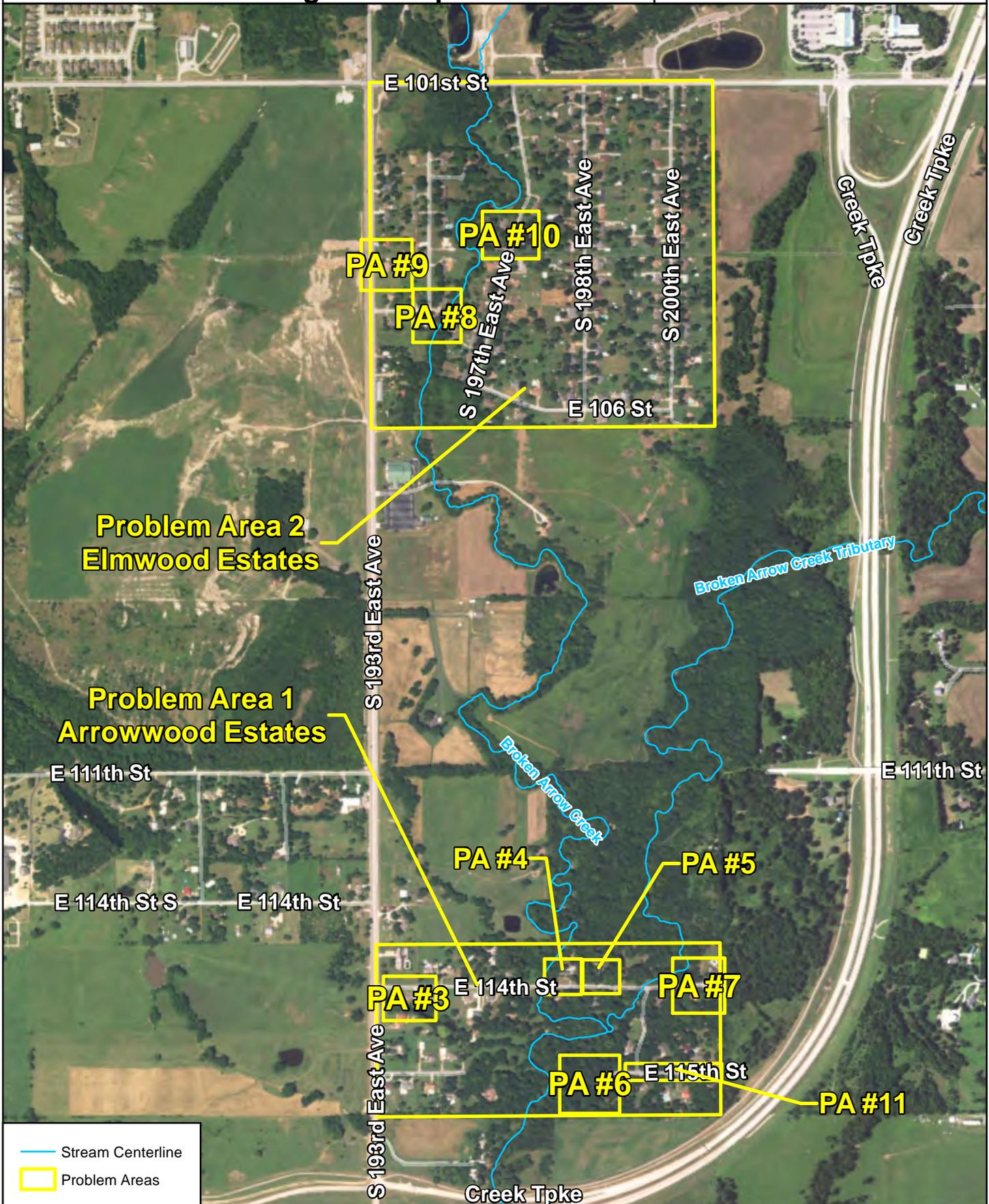
2.3.10 Problem Area 10: 10302, 10305 and 10308 South 197th East Avenue

These locations are in the Elmwood Estates subdivision. The main concerns are stream bank stabilization and the need to clean out the channel for flow conveyance.

2.3.11 Problem Area 11: Ditches along E 115th Street

This street is in Arrowwood Estates subdivision. One of the residents commented about poor drainage in this area despite having ditches along the road.

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2.4 Alternative Analysis for Problem Areas

The problem areas were studied in detail and several alternatives were analyzed to address the flooding concerns in Elmwood Estates and Arrowwood Estates subdivisions. The alternatives described in this section were analyzed focusing on an overall approach to reduce the water surface elevations through these subdivisions and improve the access to the residents by providing regional detention in upstream locations or by improving the roadway. An approximate cost estimate is included for problem areas for which alternatives are analyzed. All the cost estimates included in the report are based on the conceptual designs done for this study.

2.4.1 Problem Area 1: East 114th Street in Arrowwood Estates

Alternative 1: Acquire 6 houses + Improve East 114th Street to have 1% Annual Chance Storm (100-year) Capacity.

This alternative analyzed an option that includes acquiring 6 houses located in the 100-year floodplain near the confluence of the Broken Arrow Creek mainstem and Broken Arrow Creek Tributary along with elevating the road and improving the structures under the road to have a 100-year capacity. In existing conditions, this road starts to overtop for frequencies less than 2-year. Since the roadway is very low and there is significant tailwater downstream of the road, the only way to improve the capacity of the roadway is to elevate the road and enlarge the culverts. In existing conditions, the lowest elevation on the road is 615 feet and the 2-year and 100-year water surface elevations at the road are 617.54 feet and 622.37 feet, respectively. To achieve a 100-year capacity for the structures under this road, the road needs to be elevated to a minimum elevation of 622.5 feet and it involves approximately 1210 feet long roadway section. This roadway improvement will also require some improvements on South 199th East Avenue, the road that connects East 114th Street and East 115th Street. The existing single 12'X8' RCB under Broken Arrow Creek mainstem should be replaced with 6 – 16'X12' RCBs. The existing single 11'X6.5' RCB under Broken Arrow Creek Tributary replaced with 8-16'X11' RCBs. The existing 30" RCP between the creeks with 5-12'X10' RCBs. Since this alternative does not cause any significant reduction in the water surface elevation, the property acquisition is included to eliminate the risk of flooding to the properties within the floodplain. Approximate finish floor elevations were estimated for these properties from the existing contour and analyzing the photographs. All those houses are built at or below an elevation of 620.5 feet and will have a flood water depth of 1- foot or more during a 100-year event. The houses on the south side of East 114th Street flood from a 10-year storm event. The roadway and culvert upgrade improves the vehicular (both residential and emergency) access to the remaining properties in Arrowwood estates. This alternative is shown in **FIGURE 2-4**. The cost for this alternative is estimated at \$4,535,900 and is detailed in **APPENDIX C-1**. Including the cost to acquire the 6 houses would add an additional \$1,280,110 making the total cost estimate for this alternative approximately \$5,816,010.

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0 125 250
Feet



-  Stream Centerline
-  Culvert Replacements
-  Elevate Roadway to 622.5 FT



**Problem Area 1
Alternative 1**



**Figure
2 - 4**

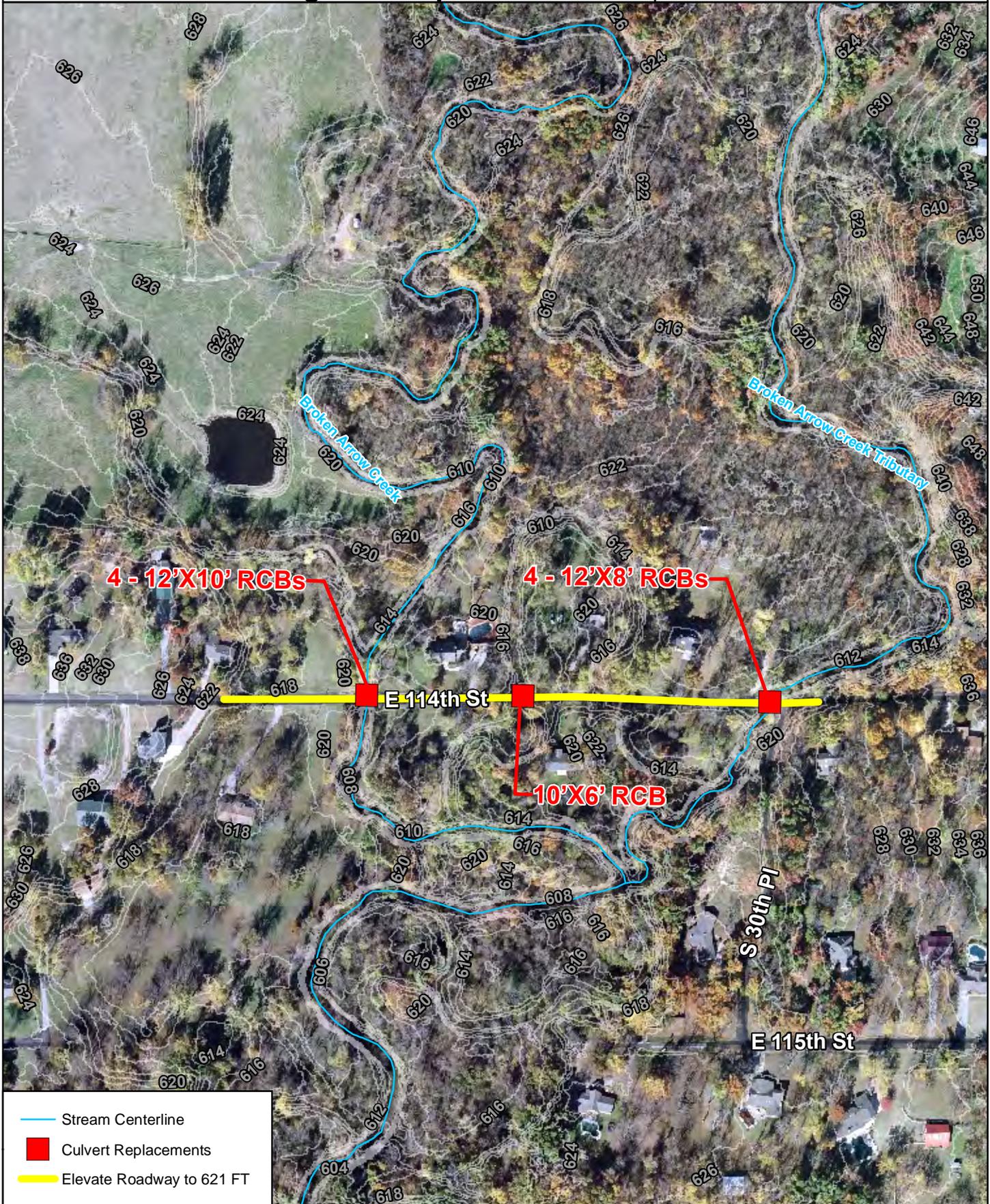
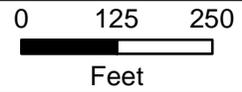
Alternative 2: Improve East 114th Street to have 10% Annual Chance Storm (10-year) Capacity.

This alternative replaces the existing structure under East 114th Street to have a capacity to convey the 10% Annual Chance (10-year) storm through it. In existing conditions, this road starts to overtop for frequencies less than 2-year. The roadway is very low and there is a significant tailwater downstream of the road. Hence, to achieve a 10-year capacity for this roadway, it needs to be elevated and the culverts need to be enlarged. The lowest elevation on the existing roadway is 615 feet and the 10-year water surface elevation at the road is 619.96 feet. To achieve a 10-year capacity for the structures under this road, the road needs to be elevated to a minimum elevation of 621 feet and it involves approximately 1150 feet long roadway section. This roadway improvement will also require some improvements on South 199th East Avenue, the road that connects East 114th Street and East 115th Street. The existing single 12'X8' RCB under Broken Arrow Creek mainstem should be replaced with 4-12'X10' RCBs. The existing single 11'X6.5' RCB under Broken Arrow Creek Tributary replaced with 4-12'X8' RCBs. The existing 30" RCP between the creeks with 10'X6' RCB. The roadway and culvert upgrade improves the vehicular (both residential and emergency) access to the properties in Arrowwood Estates during smaller and frequent storm events. Since this alternative does not lower the water surface elevation, it does not reduce the risk of flooding for properties that are flooded in a 10% Annual Chance (10-year) storm event. This alternative was analyzed as a less costly interim design to improve the existing condition in Arrowwood Estates subdivision and hence acquiring the houses in the floodplain are not considered in this alternative. This alternative is shown in **FIGURE 2-5**. The cost for this alternative is estimated at \$2,130,400 and is detailed in **APPENDIX C-2**.

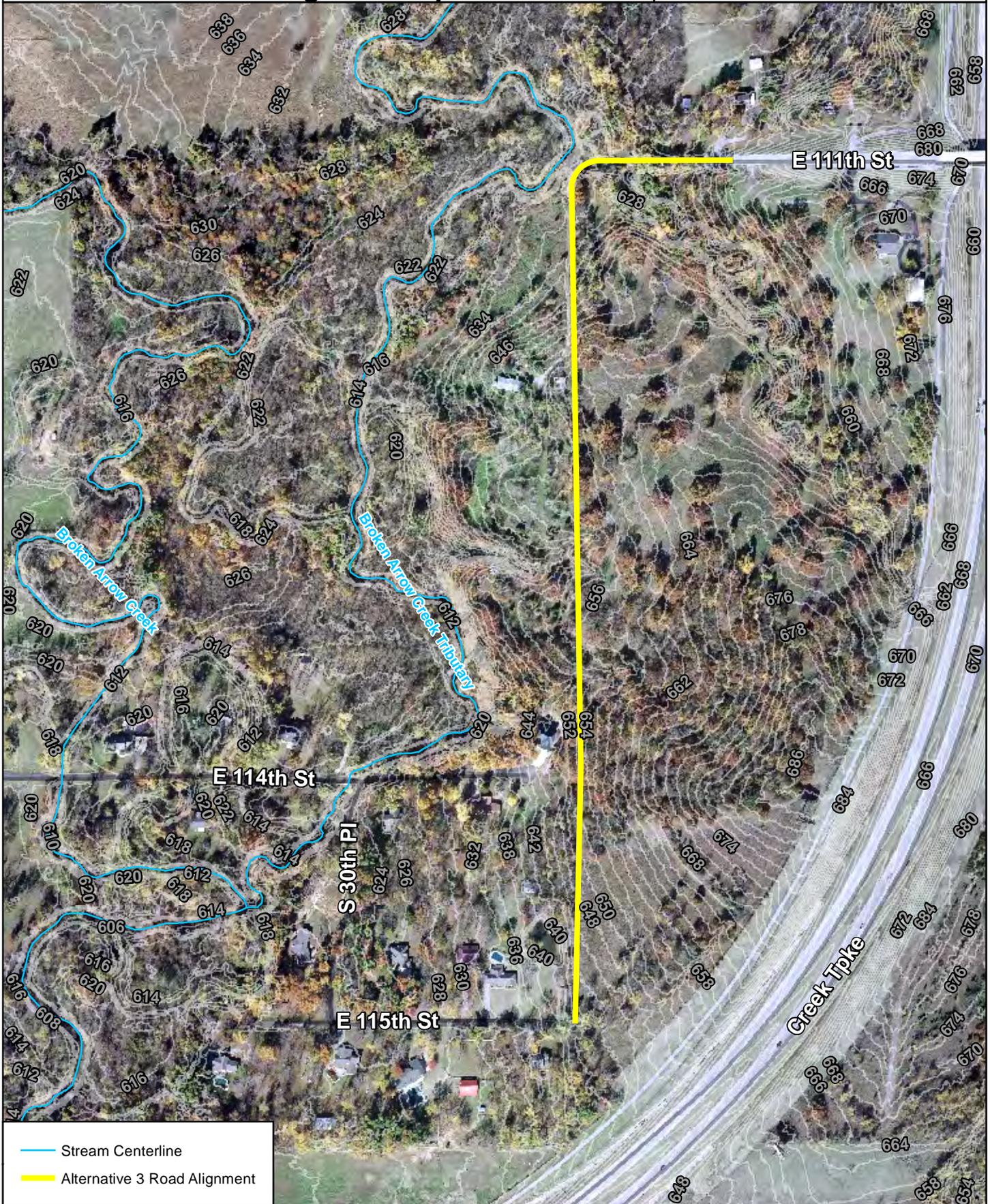
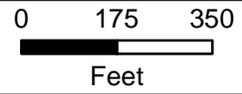
Alternative 3: Acquire 6 houses + Build a New Road in the Alignment of South 31st Street.

This alternative considered acquiring 6 houses in the 100-year floodplain near the confluence of Broken Arrow Creek Mainstem and Broken Arrow Creek Tributary along with building a new road to provide access to the houses on the east side of the creeks on East 114th Street and on East 115th Street. East 114th Street floods frequently. During a 2-year event, the road overtops by approximately 2.5 feet making it very dangerous to commute. Alternative 1 discusses the structures required to improve the capacity of the road. Instead of improving East 114th Street, this alternative includes building a new road which will not be affected by the flood. This new road will be built along the alignment of existing South 31st Street which is currently just an access road to a house from East 111th Street. This alternative requires improving approximately 750 feet of East 111th Street to the west of the Creek Turnpike and building 2350 feet of new road along South 31st Street connecting East 111th Street and East 115th Street. This 100-year alternative mitigates the flood risk by obtaining the properties in the 100-year floodplain and improving the vehicular access to the houses on east side of the creek by providing a new roadway. This new roadway alignment is shown in **FIGURE 2-6**. The cost for this new roadway is estimated at \$1,600,400 and is detailed in **APPENDIX C-3**. Including the land price to obtain a 60' Right of Way to construct this roadway would add an additional \$50,000 and the cost to acquire the 6 houses would add an additional \$1,280,110 making the total cost estimate for this alternative approximately \$2,930,510.

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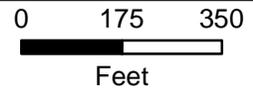
Alternative 4: Acquire 6 houses + Build a New 100-year Capacity Road Along East 115th Street.

This alternative includes acquiring 6 houses on East 114th Street in the 100-year floodplain near the confluence of Broken Arrow Creek Mainstem and Broken Arrow Creek Tributary as well as building a new road and a bridge at East 115th Street to provide access to the houses on the east side of the creeks. Currently there is no roadway crossing the creek within the platted East 115th Street Right of Way. The new structure for East 115th Street is a 9 span 100-foot Type IV PC beam bridge. The proposed bridge will have a top of road elevation of 624 feet. The existing roads on both sides of the creek have an elevation of 624 feet where it would tie in. This alternative causes a slight increase in the 100-year water surface elevation that would need to be mitigated by providing additional storage during the design of the project. This alternative improves the vehicular (both residential and emergency) access to the properties on the east side of Arrowwood Estates. This proposed new roadway alignment is shown in **FIGURE 2-7**. The cost for this alternative is estimated at \$5,261,250 and including the cost to acquire the 6 houses would add an additional \$1,280,110 making the total cost estimate for this alternative approximately \$6,541,360. Cost estimate for the new road is detailed in **APPENDIX C-4**.

Alternative 5: Build a New 10-year Capacity Bridge along East 115th Street

This alternative proposes a new bridge at East 115th Street to provide access to the houses on the east side of the creeks on East 114th Street and to the houses on East 115th Street. Currently there is no roadway crossing the creek at East 115th Street. A 7 span 75-foot Type III PC beam bridge would be required to connect East 115th Street. The proposed bridge will have a top of road elevation of 621 feet. The existing roads on both sides of the creek have an elevation of 624 feet where it would tie in. This alternative causes a slight increase in the 10-year and 100-year water surface elevations which would require some mitigation by providing additional storage during the design of the project. This alternative improves the vehicular (both residential and emergency) access to the properties on the east side of Arrowwood Estates and it do not consider acquiring any houses. This proposed new roadway alignment is shown in **FIGURE 2-8**. The cost estimate for this alternative is \$3,333,200 and is detailed in **APPENDIX C-5**.

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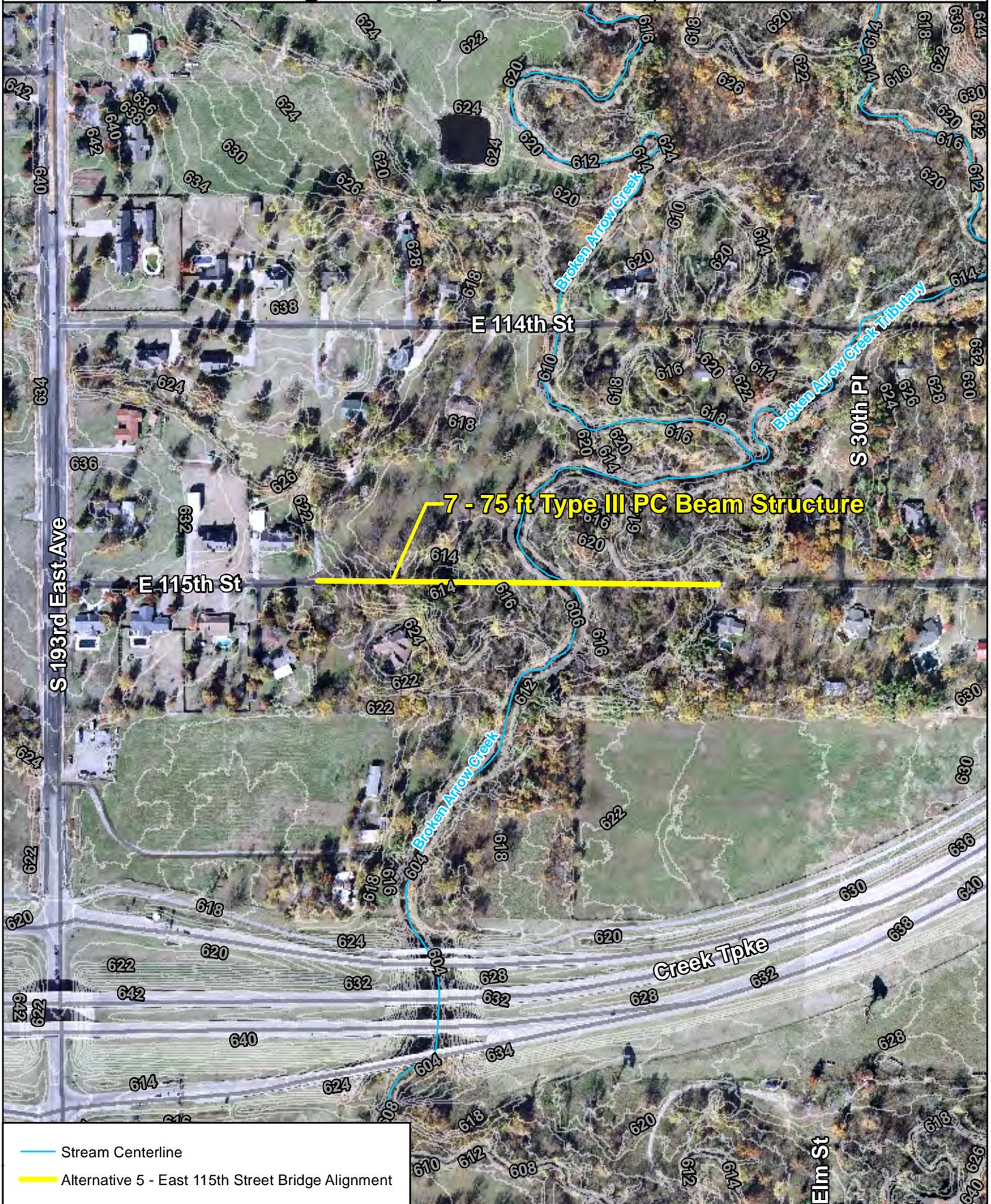
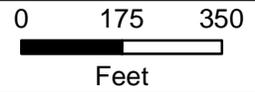


**Problem Area 1
Alternative 4**



**Figure
2 - 7**

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-  Stream Centerline
-  Alternative 5 - East 115th Street Bridge Alignment



**Problem Area 1
Alternative 5**

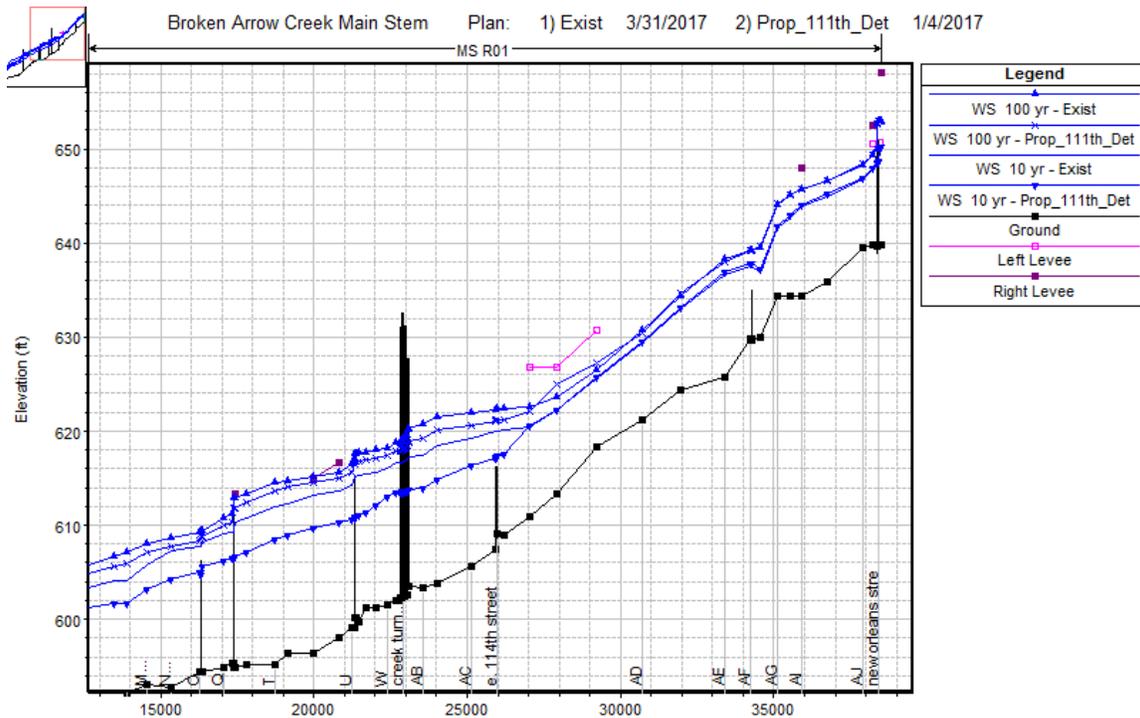
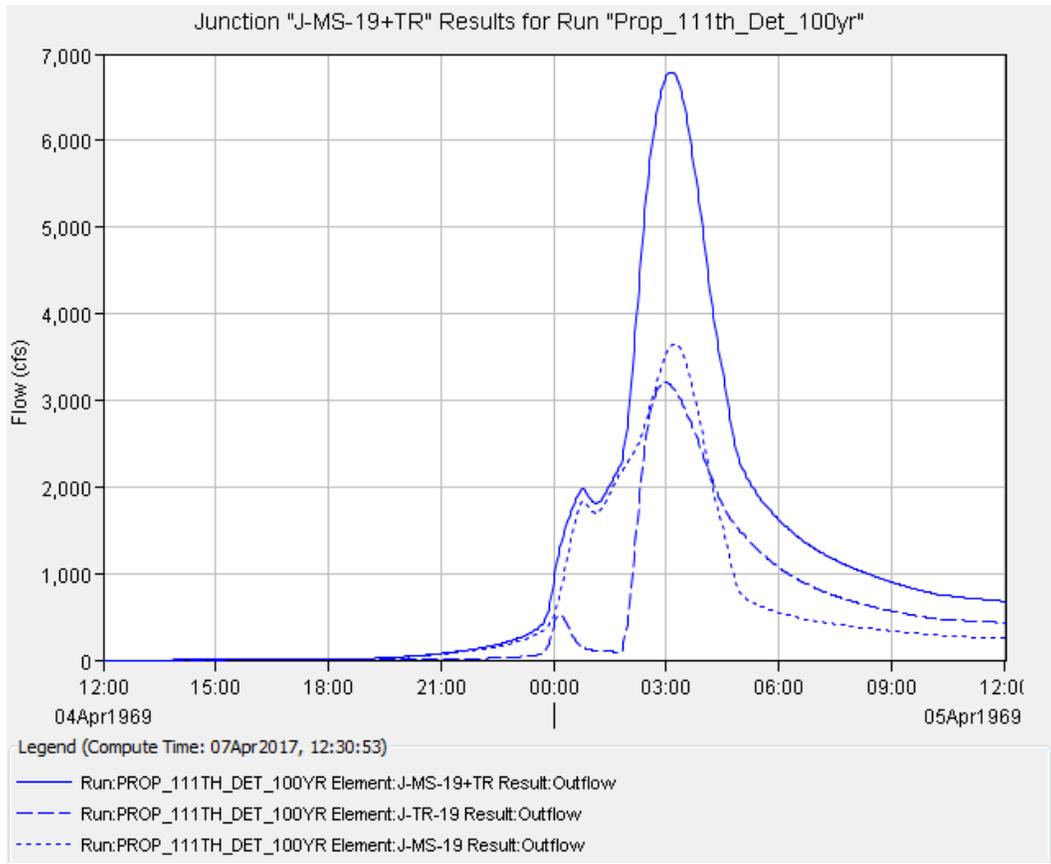


**Figure
2 - 8**

Alternative 6: Detention Facility on Broken Arrow Creek Tributary

This alternative analyzes a detention facility on Broken Arrow Creek Tributary to the west of the Creek Turnpike. The pond would have a top of dam elevation of 642 feet and at this elevation it has a surface area of 55 acres. The outlet structures used in this pond analysis include a 24" RCP at flow line elevation of 616 feet, 10'X10' concrete tower with top elevation at 634 feet and a 50-foot long spillway at 635.5 feet. The 100-year peak inflow is 6,760 cfs. The peak outflow from the pond is 3,178 cfs. The 100-year peak elevation is 639.8 feet and the pond has a peak storage of 977 acre-feet at this elevation. The 10-year peak inflow is 3,557 cfs and the corresponding peak outflow is 379 cfs. The pond reduces the peak flow downstream of the pond. However, at the confluence, the delayed peak from the pond coincides with the peak flow from Broken Arrow Creek mainstem, as shown in **FIGURE 2-9**, and some of the benefits are lost. The 100-year peak flow rate at the confluence of Broken Arrow Creek Mainstem and the tributary is reduced from 9,015 cfs in existing condition to 6,791 cfs and the 100-year water surface elevation near East 114th Street lowers from 622.38 feet to 621.16 feet. The 10-year peak flow rate near the confluence reduces from 4909 cfs to 2123 cfs and the 10-year water surface elevation is lowered from 620.03 feet to 617.43 feet. This pond would be categorized as a high hazard structure. Since this alternative does not cause any significant reduction in the 100-year water surface elevation, the property acquisitions are included to eliminate the risk of flooding to the properties within the floodplain. This alternative eliminates flooding of the structures during a 10-year event. Thus, the benefit of this pond is a lower water surface elevation near East 114th Street resulting in less property damage during flood events. The reduction in flow rate allows 50% Annual Chance (2-year) Storm event to pass through the structure without overtopping and thus improves the vehicular access during a 50% Annual Chance (2-year) Storm event. Since the pond reduces the flow rate and water surface elevations near the confluence, it can be combined with culvert and roadway improvements at East 114th Street to have a better capacity for this road. The proposed hydrograph at the confluence and the existing and proposed 10-year and 100-year water surface profiles are shown in **FIGURE 2-9** below. The cost estimate for this alternative is \$26,282,200 and is detailed in **APPENDIX C-6**. Including the cost to acquire the 6 houses adds \$1,280,110 and the purchase of land required for the construction of this detention facility would add an additional \$681,525 making the total cost estimate for this alternative approximately \$28,243,835.

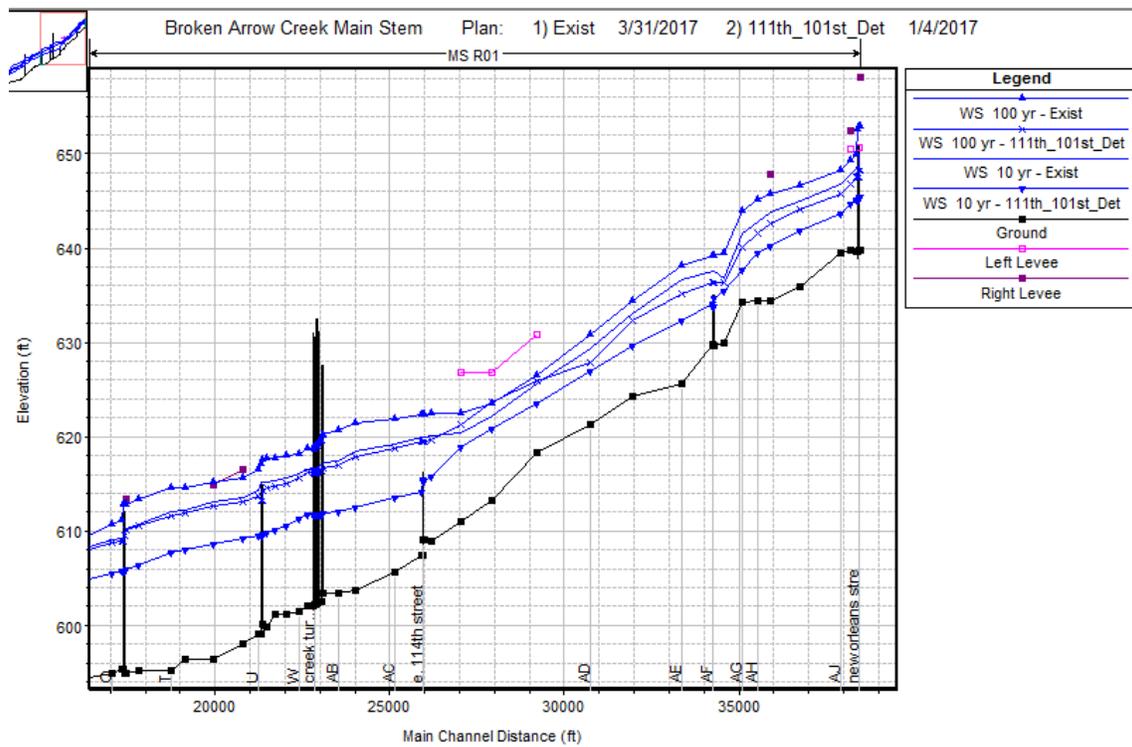
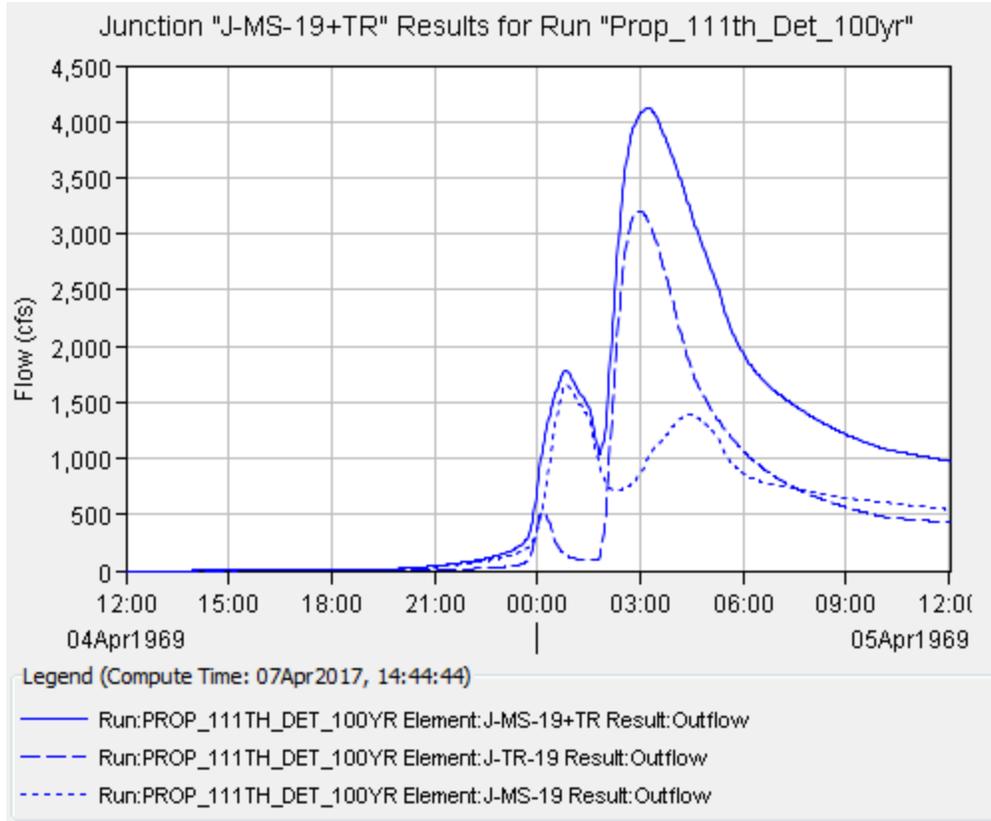
Figure 2-9 Problem Area 1, Alternative 6



Alternative 7: Detention in Broken Arrow Creek Tributary and Broken Arrow Creek Mainstem

This alternative analyzed two detention facilities - one in Broken Arrow Creek Tributary as described in Alternative 6 and another one in Broken Arrow Creek Mainstem to the north of New Orleans Street to determine the combined effect of these ponds. The pond in Broken Arrow Creek Mainstem assumed a top of dam elevation of 659.5 feet and at this elevation it has a surface area of 39 acres. The outlet structures used in this pond analysis include a 6'X6' RCB with a flow line elevation of 639 feet and a 50-foot long spillway at 653.5 feet. The 100-year peak inflow to the pond is assumed to be 3,779 cfs. The peak outflow from the pond is 1307 cfs. The 100-year peak elevation in the pond is 656 feet and the pond has a peak storage of 506 acre-feet at this elevation. The 10-year peak inflow to the pond is 2,119 cfs and the peak outflow from the pond is 490 cfs. The 100-year peak hydrographs at the confluence of Broken Arrow Creek mainstem and Tributary with both ponds in place are shown below. The 100-year peak flow rate at the confluence is reduced from 9,015 cfs in existing condition to 4,117 cfs and the 100-year water surface elevation near East 114th Street lowers from 622.38 feet to 619.57 feet. The 10-year peak flow rate near the confluence reduces from 4,909 cfs to 951 cfs and the 10-year water surface elevation is lowered to 615.34 feet. Lowering the water surface eliminates four properties on the north side of East 114th Street from the 100-year floodplain. Per the approximate finish floor elevation, the properties on the south side of East 114th Street still have a chance to flood. A detailed survey needs to be done to determine the actual finished floor elevations of the buildings on the south side. Reduction in peak flow rate improves the roadway capacity to a 10-year frequency. The lowest point on the road is at 615 feet. This alternative benefits both Arrowwood Estates and Elmwood Estates subdivisions by lowering the water surface elevations. Thus, this analysis can be counted as an alternative to Problem Area 2 as well. Vehicular access would be improved to the Arrowwood Estates subdivision. The existing and proposed 10- and 100-year profiles are shown in **FIGURE 2-10** below. The cost estimate for this alternative is \$47,246,700 and is detailed in **APPENDIX C-7**. Including the cost to acquire the 6 houses adds 1,280,110 and the purchase of land required for the construction of these two detention facilities would add an additional \$1,136,525 making the total cost estimate for this alternative approximately \$49,663,335.

Figure 2-10 Problem Area 1, Alternative 7

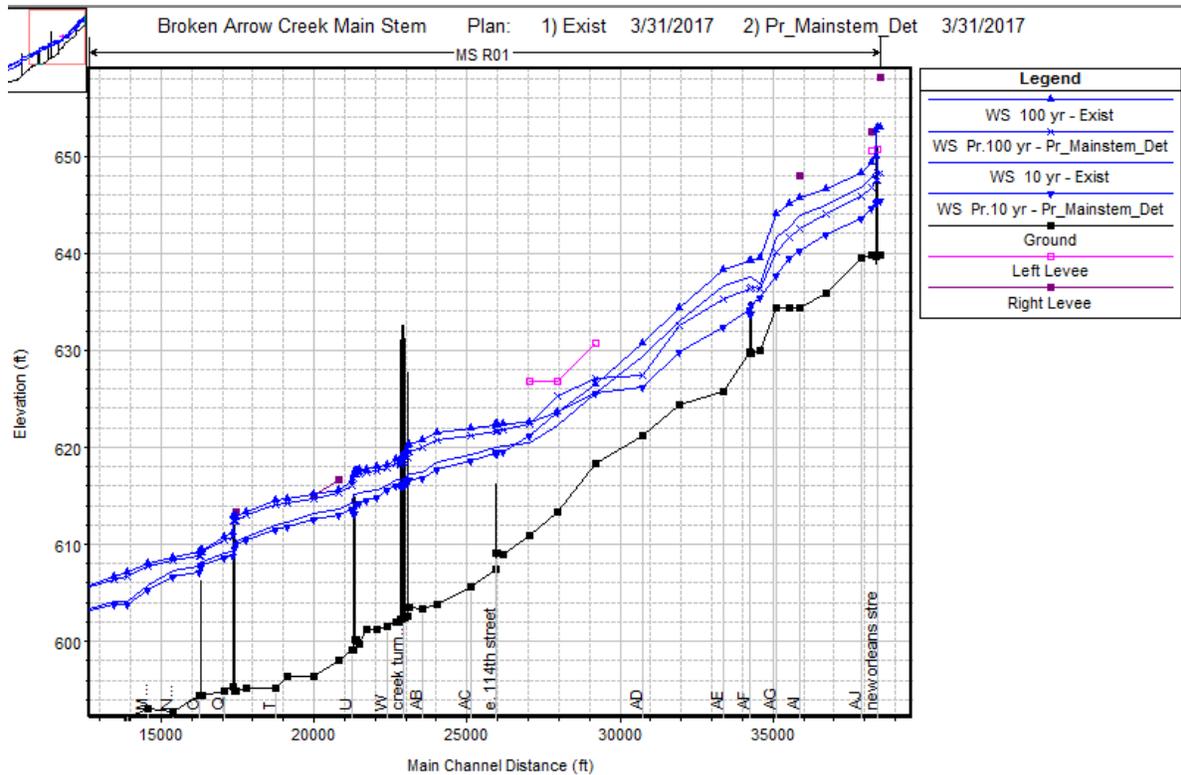
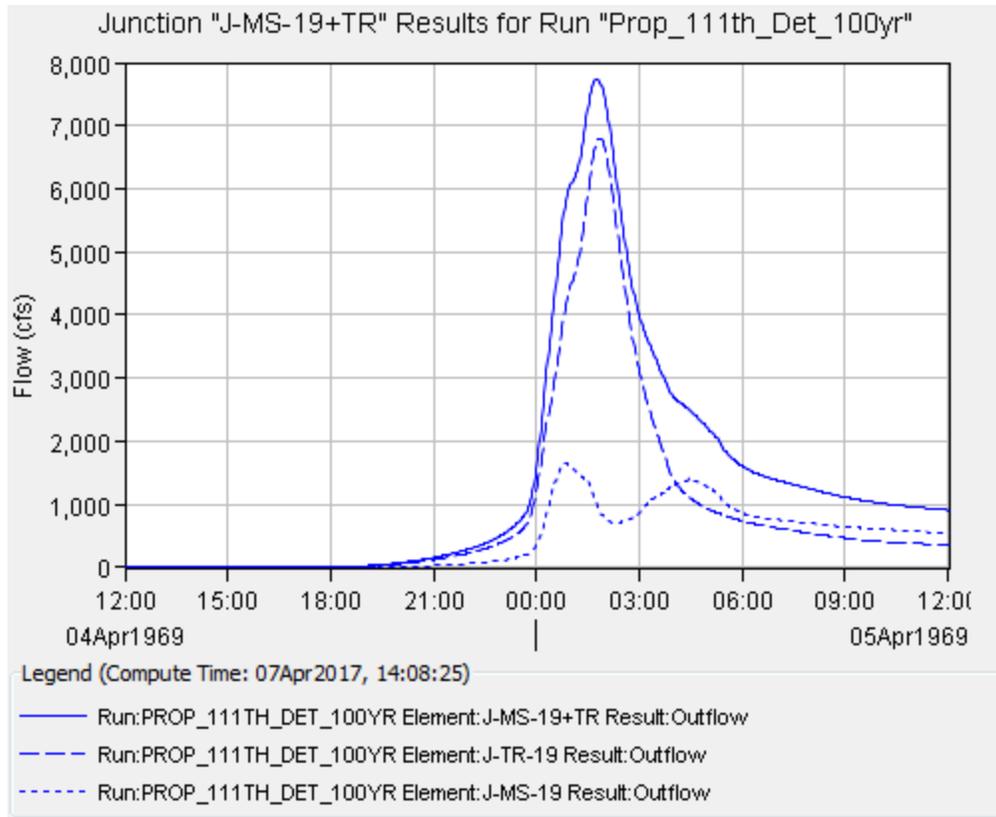


2.4.2 Problem Area 2: East 114th Street in Arrowwood Estates

Alternative 1: Detention Facility in Broken Arrow Creek Mainstem

This alternative analyzes a detention facility on Broken Arrow Creek Mainstem to the north of East 101st Street. The pond assumed a top of dam elevation of 659.5 feet and at this elevation it has a surface area of 39 acres. The outlet structures used in this pond analysis include a 6'X6' RCB with a flow line elevation of 639 feet and a 50 feet long spillway at 653.5 feet. The 100-year peak inflow to the pond is assumed to be 3,779 cfs. The peak outflow from the pond is 1,307 cfs. The 100-year peak elevation in the pond is 656 feet and the pond has a peak storage of 506 acre-feet at this elevation. The 10-year peak inflow to the pond is 2,119 cfs and the peak outflow from the pond is 490 cfs. The 100-year peak flow rate at the confluence of Broken Arrow Creek Mainstem and Tributary is reduced from 9,015 cfs in existing condition to 7,728 cfs and the 100-year water surface elevation near East 114th Street lowers from 622.38 feet to 621.71 feet. The 10-year peak flow rate near the confluence reduces from 4,909 cfs to 3,997 cfs and the 10-year water surface elevation is lowered from 620.03 feet to 619.47 feet. Even though the water surface elevations are lowered near the confluence, this alternative does not remove any structures from the 100-year floodplain near the confluence of Broken Arrow Creek Mainstem and its tributary. Thus, the Arrowwood Subdivision does not receive much benefit from this pond and this alternative requires acquiring 7 properties near the East 114th Street in Arrowwood Estates. The structures to the north of East 114th Street will be avoided from frequent flood events as they will be removed from the 10-year floodplain. Since this proposed pond is in the mainstem, Elmwood Estates subdivision receives the most benefit from this pond. The water surface elevation for the 100-year and 10-year storm events are lowered by 2 to 4 feet through this subdivision and several buildings in this subdivision are removed from the 100-year floodplain. The pedestrian bridge in Elmwood Estates will have a 10-year capacity when this pond is built. In existing condition, this structure has less than a 2-year capacity. The existing and proposed 10- and 100-year profiles are shown in **FIGURE 2-11** below. The cost estimate for this alternative is estimated at \$20,964,500 and is detailed in **APPENDIX C-8**. Including the cost to acquire the 6 houses adds 1,280,110 and the purchase of land required for the construction of this detention facility would add an additional \$455,000 making the total cost estimate for this alternative approximately \$22,699,610.

Figure 2-11 Problem Area 2, Alternative 1



2.4.3 Problem Area 3: 19310 East 114th Street South

From the existing condition analysis, approximately 2.6 acres of area drains to this location. The property owner has a SMD Drain and swale system through the west side of their property. This alternative assumes an SMD with an 18" cross drain that would connect to the existing SMD on the property owner's yard and then drain to the creek through the existing storm sewer. This alternative also includes some grading on the north side of East 114th Street to drain water in the direction of proposed SMD. This proposed alternative is shown in **FIGURE 2-12** below. The cost for this alternative is estimated at \$16,400 and is detailed in **APPENDIX C-9**.

2.4.4 Problem Area4: 19769 East 114th Street South

The inadequate capacity of the culverts under East 114th Street is discussed under Problem Area 1 and alternatives were presented to address this issue. General channel/ditch cleaning to remove debris and overgrown vegetation can be done to improve conveyance in the channel. This area is private property and there are no drainage easements along the channel.

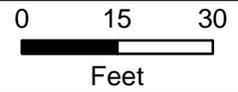
2.4.5 Problem Area5: 19825 East 114th Street South

The owner comments were about general flooding concerns and the lack of culvert capacity. Since the culvert improvements are already discussed in detail no additional alternatives are presented.

2.4.6 Problem Area 6: 19825 East 115th Street South

The owners requested that the creeks be cleaned and more capacity provided in the culverts. This house appears to be above the 100-year elevation but the floodplain mapping does clip the garage. The property owner can coordinate with City officials to determine if there may be assistance in obtaining an elevation certificate and a Letter of Map Amendment for the structure. General channel/ditch cleaning to remove debris and overgrown vegetation can be done to improve conveyance in the channel. This area is private property and there are no drainage easements along the channel.

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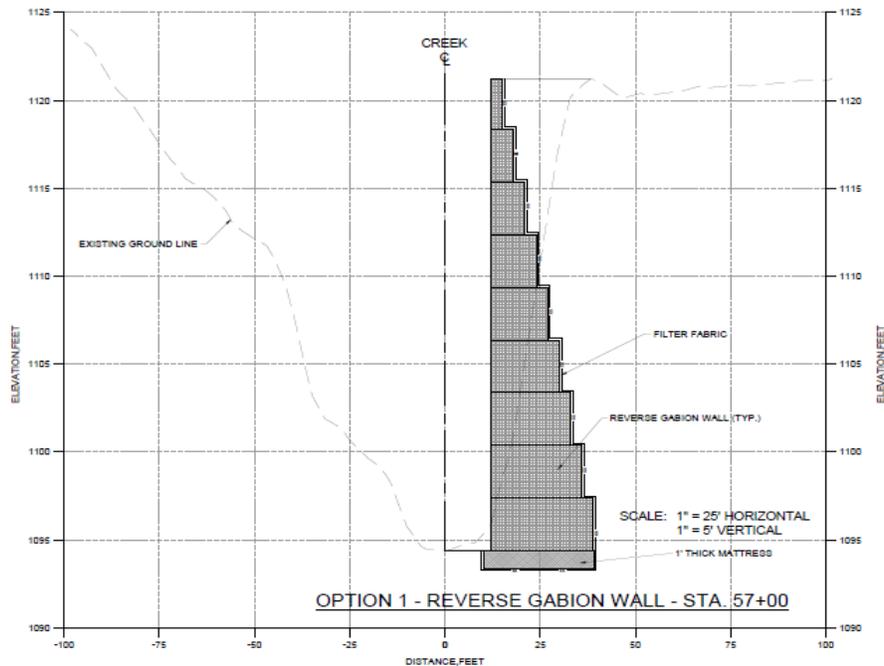


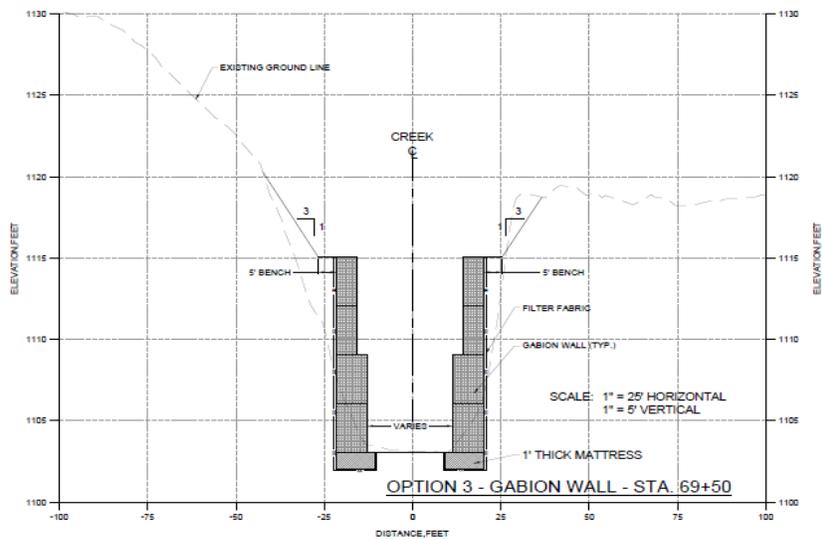
Existing SMD
Existing Storm Sewer
Alternative
Additional SMD
Add 18" RCP

2.4.7 Problem Area 7: 20024 & 20073 East 114th Street South

Upstream and downstream of East 114th Street in Broken Arrow Creek Tributary, the channel needs to be cleaned up to clear it from all the debris and provide some erosion control measures. The easiest and simplest solution for erosion control is to protect the toe, develop a floodplain bench and tie a moderate slope back to the natural grade. Riprap would be placed at the existing toe and if necessary the bank would be tied back at 2:1 slope or to a point stable vegetation can be established. The rock toe would prevent undermining of the banks during low flows and the vegetative cover provides protection from moderate flows. This method would require greater construction easements for excavating the slope back and can be applied only where the channel can be widened.

Another method that can be utilized, where there is limited space to widen the floodplain is, gabion walls. These walls can provide a near vertical bank slope. If the vertical walls are installed at the existing toe of the bank, the conveyance area can be reduced which may adversely impact the water surface elevation. Another option is to use shorter vertical gabion wall with a bench established at the top and then the remaining slope would tie back to the existing ground using 3:1 vegetated and maintainable slopes. Gabion walls can also be done stair stepped facing the creek.





Since most of the erosion mentioned in this area are in the backyards or near the streets there is not much room to widen the channel. Hence, gabion walls are a practical erosion control option to consider for these areas. Any erosion control measures analyzed here need detailed field investigation and geotechnical analysis before designing it, therefore no cost estimate is included.

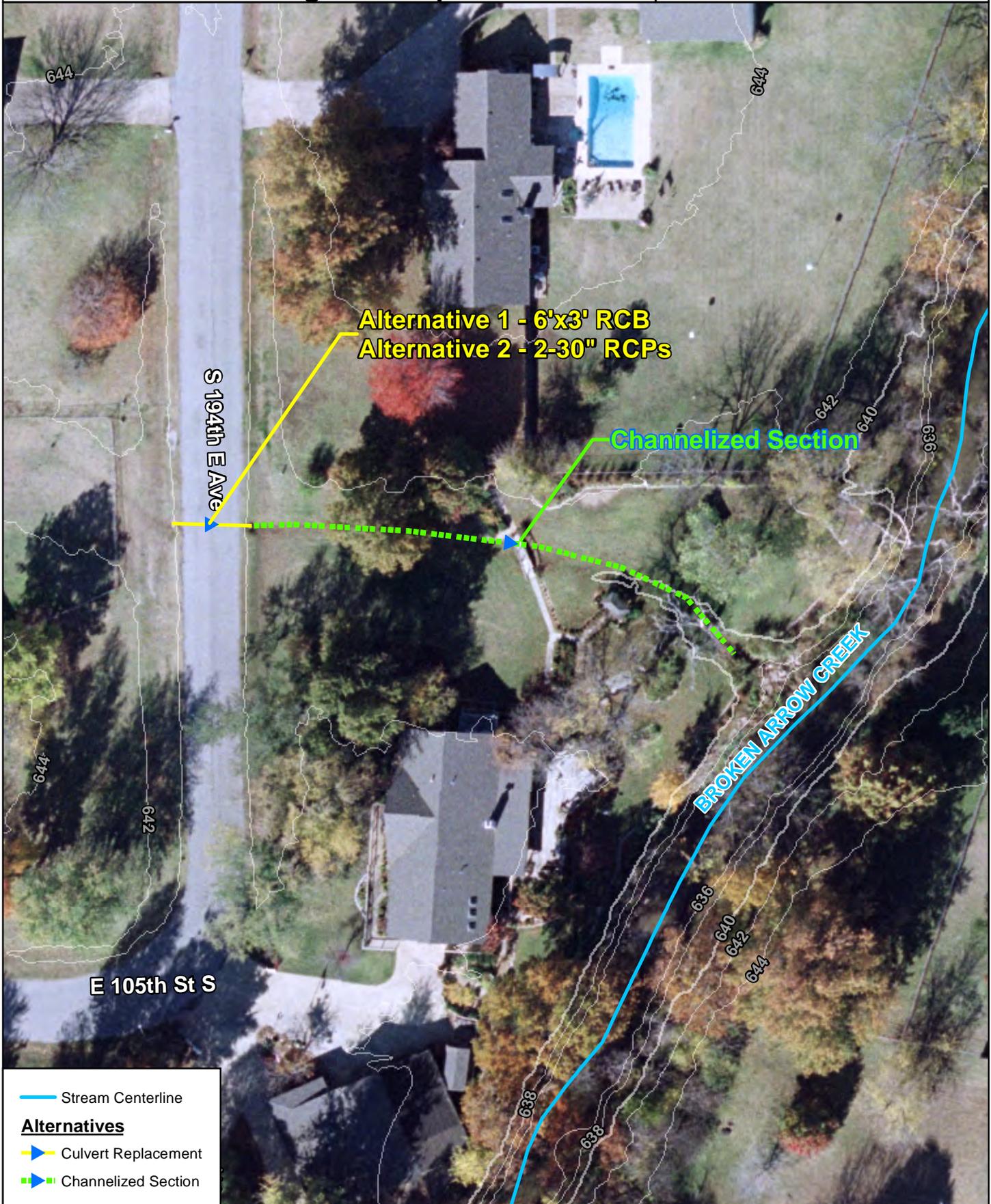
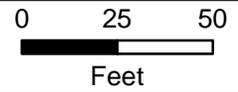
2.4.8 Problem Area 8: 10407 South 194th East Avenue

In existing conditions, this pipe under 194th East Avenue drains approximately 17 acres and the 100-year peak flow rate at this location is approximately 108 cfs. This entire area is within the 100-year floodplain of Broken Arrow Creek mainstem. The existing ground elevation is 642 feet near the existing pipe and 640 feet near the creek. The 10-year water surface elevation in Broken Arrow Creek mainstem at this location is 642.72 feet.

Alternative 1 - A grass lined trapezoidal channel with a bottom width of 2 feet and 4:1 side slopes can be graded through the north side of the yard to convey the 100-year discharge to the creek. The existing 24" RCP under South 194th East Avenue needs to be replaced with a 6'X3' RCB to eliminate water ponding on the west side of this street. This proposed channel will have a top width of 22 feet and a water depth of 2.5 feet. With an assumed channel slope of 0.5%, the channel velocity is 3.6 fps. The cost for this alternative is \$171,000 and is detailed in **APPENDIX C-10**.

Alternative 2 - The 10-year peak flow at this location is approximately 65 cfs. A 10-year alternative would require replacing the existing 24" RCP under South 194th East Avenue with double 30" RCPs and a grass lined trapezoidal channel with a 2-foot bottom width and 4:1 side slopes to carry the water to Broken Arrow Creek mainstem. This proposed 10-year channel has a top width of 18 feet and water depth of 2 feet. The channel velocity is 3 fps. The cost for this alternative is estimated at \$84,100 and is detailed in **APPENDIX C-11**. Proposed culverts and channel alignment for both Alternative 1 and Alternative 2 are shown in **FIGURE 2-13**.

Elmwood Estates & Arrowwood Estates Flood Mitigation Report



— Stream Centerline

Alternatives

— Culvert Replacement

— Channelized Section



**Problem Area 8
Alternative 1 & 2**



**Figure
2 - 13**

2.4.9 Problem Area 9: 10313 South 193rd East Avenue

This house is lower than E. 193rd East Avenue and the drive way slopes down to the garage. Water from the road does not appear to drain into the property. The roadway is curbed with storm sewer that drains to the Broken Arrow Creek mainstem. A slotted drain across the driveway can help to collect the water running down the driveway before it reaches the garage. If this water collected from the drive way and the water in the ponding area can be connected to the existing storm sewer system, it should help to alleviate the flooding issues on the front side of this property.

The backyard is the recipient of flow from several lots to the north. A swale could be graded through the backyards to convey the water to the cross drain proposed in Problem Area 6. To convey the 100-year event, approximately 40 cfs, a trapezoidal channel with a 2-foot bottom width and 4:1 side slopes could convey the water with an average water depth of 1.7 feet and velocity of 2.8 fps to the culvert under South 194th East Avenue. All of this area is private property and there are no drainage easements. The cost for this alternative is estimated at \$163,500 and is detailed in **APPENDIX C-12**. This proposed channel alignment is shown in **FIGURE 2-14**.

2.4.10 Problem Area 10: 10104, 10302, 10305 and 10308 South 197th East Avenue

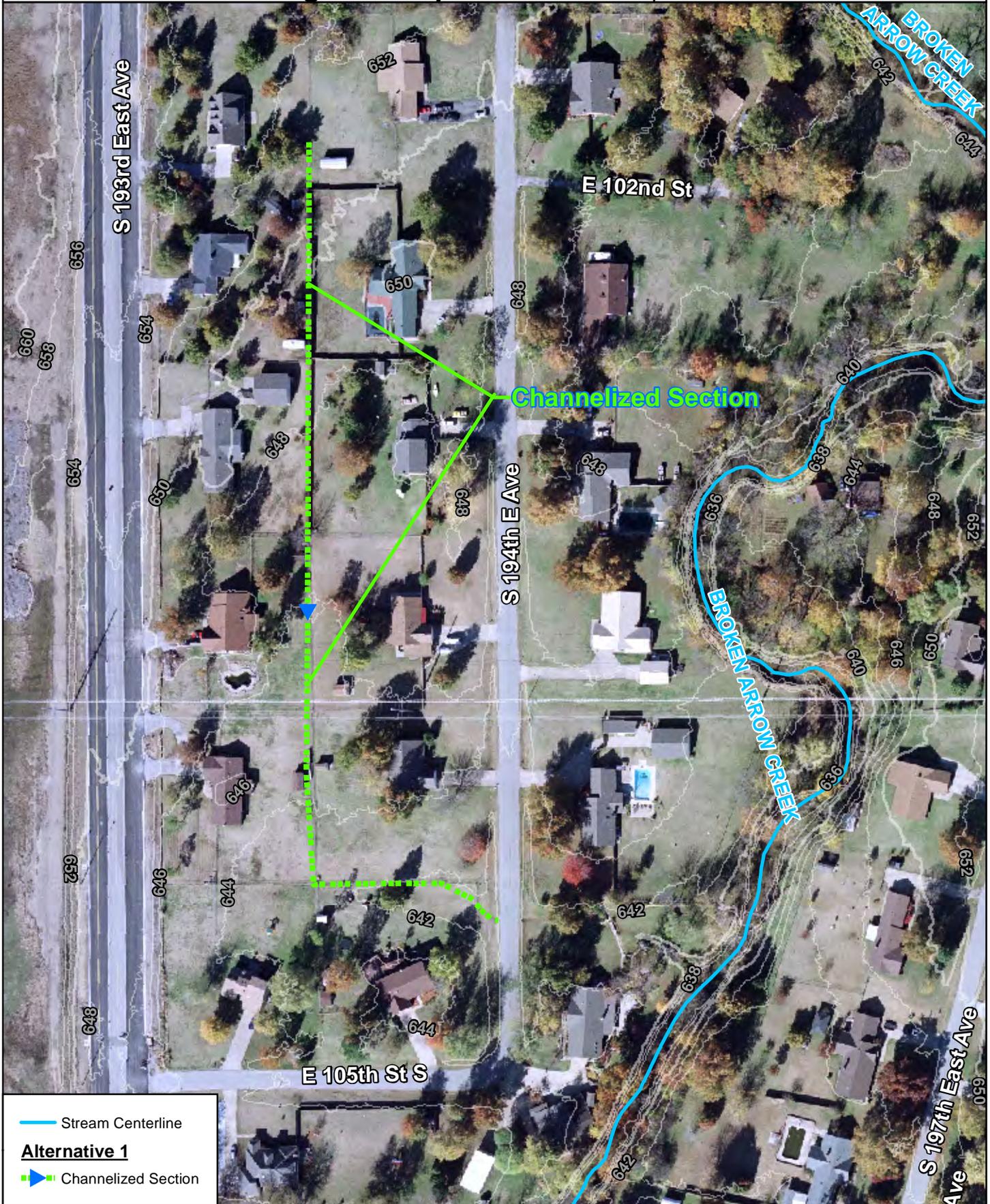
General channel/ditch cleaning to remove debris and overgrown vegetation can be done to improve conveyance in the channel. This area is private property and there are no drainage easements along the channel. There are several areas of severe bank erosion. The methods described in Problem Area 5 could be utilized at this location as well.

2.4.11 Problem Area 11: Ditches along E 115th Street

In existing condition, this street has ditches on both sides of the road. The ditch on the south side remains open until it discharges into the creek. The ditch on the north side is taken to the creek through a pipe from South 199th East Avenue. The pipe sizes are not available for this area. Approximately 6 acres drain to this area and during a 100-year event this area might receive about 25 to 30 cfs of runoff. The sizes of the existing ditches are not available. To convey a 100-year storm, the ditches on both sides need to be improved with a trapezoidal channel with a 0.5 feet bottom width, 3:1 side slopes, approximately 1.75 feet deep. The pipe that discharges into the creek from South 199th East Avenue needs to be replaced with a 24" RCP. This improvement will require replacing several driveway culverts too. General clearing of the ditch would improve the conveyance capacity of the existing system.

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0 75 150
Feet



-  Stream Centerline
- Alternative 1**
-  Channelized Section

**Problem Area 9
Alternative 1**

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& ASSOCIATES, LLC
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**Figure
2 - 14**

Section 3. CONCLUSION

Based on the existing condition, this study evaluated the problem areas in the Elmwood Estates and Arrowwood Estates subdivisions. Several alternatives were analyzed to assess the situation and mitigate the flooding in this area. The mitigation of flooding in the local problem areas are less expensive compared to the general problem areas. Most of the local problems are related to the general problems in this area. Since these subdivisions are located near the confluence of Broken Arrow Creek Mainstem and its tributary, the flow rates are very large even for a small rain event making the flood mitigation for these events expensive. This report provides a summary of the flooding and drainage problems within Arrowwood Estates and Elmwood Estates subdivisions that the City of Broken Arrow can use as a resource for decision making on future mitigation actions.

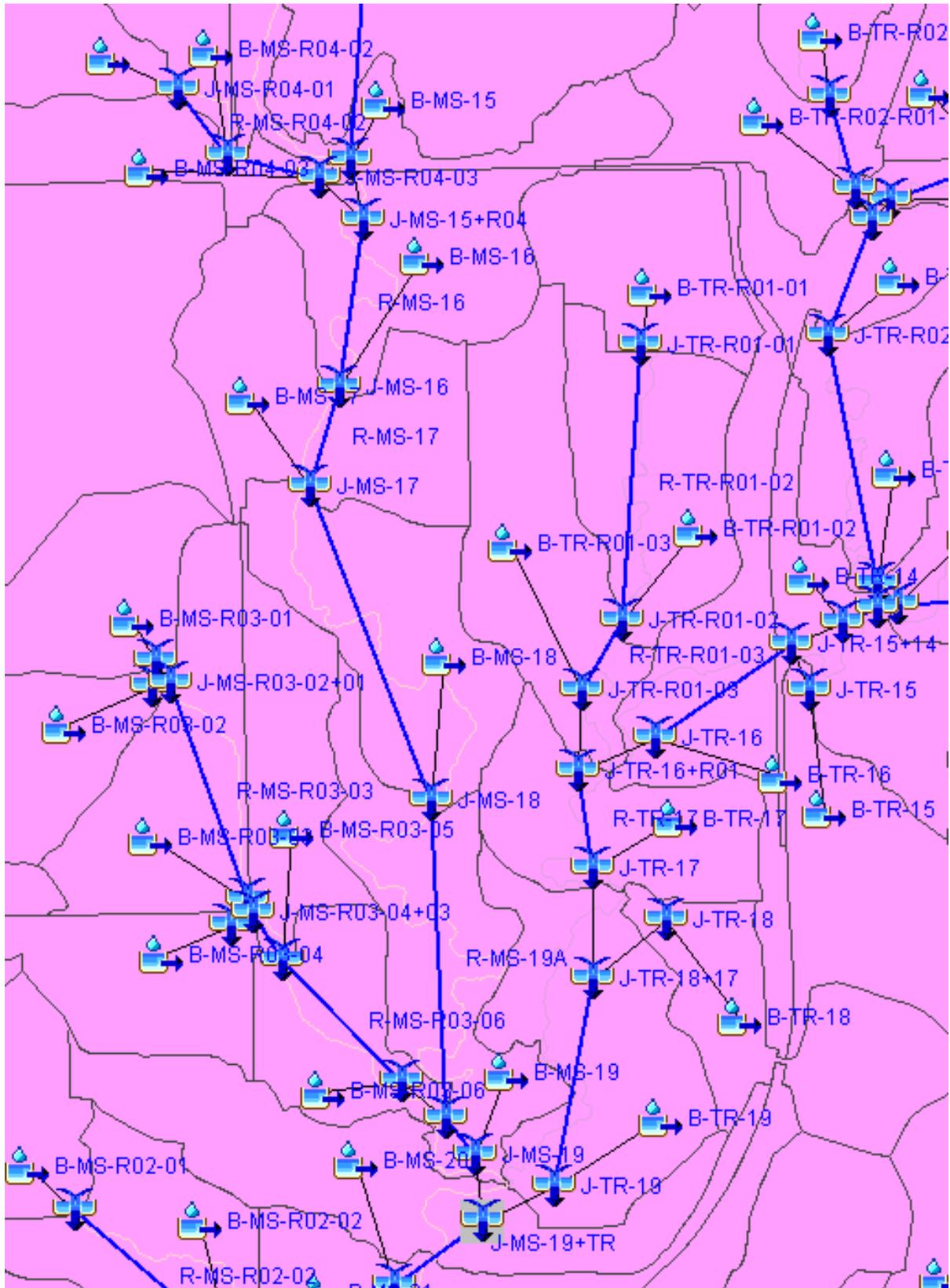
Appendix-A

Hydrologic Coefficients for Existing Conditions

Hydrologic Coefficients				
HMS ID	Area (acres)	Initial Abstarction (inches)	CN	Lag (min)
B-MS-15	45.44	0.7	73	16.8
B-MS-16	49.92	0.5	78.7	12
B-MS-17	63.36	0.7	74.8	14
B-MS-18	57.6	0.8	71.3	13.1
B-MS-19	56.96	1.1	64.9	30.3
B-MS-20	67.2	0.6	75.7	13.8
B-MS-R03-01	40.96	0.8	71.2	18.9
B-MS-R03-02	42.88	0.8	71	22.7
B-MS-R03-03	52.48	0.8	71	20
B-MS-R03-04	39.04	0.6	76.4	10.9
B-MS-R03-05	35.84	0.7	74.1	15.8
B-MS-R03-06	33.28	0.8	70.4	20.8
B-MS-R04-01	43.52	0.6	77	15.4
B-MS-R04-02	43.52	0.7	73.2	11.7
B-MS-R04-03	50.56	0.5	80.1	10.3
B-TR-14	44.8	0.8	72.2	14.2
B-TR-15	61.44	0.7	73.2	15.3
B-TR-16	53.76	0.9	69.7	13.2
B-TR-17	42.24	1	67.4	14.1
B-TR-18	48	0.8	70.8	15.1
B-TR-19	64.64	0.8	70.5	12.6
B-TR-R01-01	40.32	0.5	79	10.4
B-TR-R01-02	49.28	0.6	75.6	12.7
B-TR-R01-03	58.24	0.9	69.2	16.9
B-TR-R02-11	40.32	0.6	77.7	17.6

**Appendix-B
HEC-HMS Schematic
And
HEC-HMS Flowrates**

HEC-HMS Connectivity for the Study Area



Broken Arrow Creek Flood Mitigation

Existing Flow Rates (CFS)

HMS Junction	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year	Drainage Area, mi ²
B-MS-15	52	92	125	168	198	235	326	0.07100
B-MS-16	92	149	194	253	293	342	462	0.07800
B-MS-17	85	149	201	269	315	374	515	0.09900
B-MS-18	67	123	170	232	275	329	460	0.09000
B-MS-19	23	51	76	110	133	164	240	0.08900
B-MS-20	99	168	224	297	347	409	560	0.10500
B-MS-R03-01	38	71	98	134	159	190	266	0.06400
B-MS-R03-02	35	65	91	124	147	176	248	0.06700
B-MS-R03-03	47	87	120	164	195	234	329	0.08200
B-MS-R03-04	67	112	149	197	229	269	366	0.06100
B-MS-R03-05	44	77	105	141	165	196	271	0.05600
B-MS-R03-06	28	53	73	101	119	143	201	0.05200
B-MS-R04-01	63	107	141	187	217	255	348	0.06800
B-MS-R04-02	61	108	145	196	230	273	378	0.06800
B-MS-R04-03	104	168	218	282	324	378	505	0.07900
B-TR-14	51		130	176	208	248	346	0.07000
B-TR-15	74	132	179	241	284	337	467	0.09600
B-TR-16	55	105	148	204	244	293	415	0.08400
B-TR-17	35	71	102	144	173	209	301	0.06600
B-TR-18	50	94	130	177	210	252	353	0.07500
B-TR-19	75	138	191	261	309	370	519	0.10100
B-TR-R01-01	80	130	169	220	253	296	397	0.06300
B-TR-R01-02	76	129	172	227	265	312	426	0.07700
B-TR-R01-03	50	98	138	191	228	275	390	0.09100
B-TR-R02-11	55	93	123	162	189	222	301	0.06300
J-MS-15	1061	1621	2124	2790	3237	3764	5291	2.92600
J-MS-15+R04	1081	1649	2161	2836	3287	3821	5374	3.14100
J-MS-16	1074	1645	2150	2822	3272	3809	5341	3.21900
J-MS-17	1078	1652	2156	2821	3260	3798	5334	3.31800
J-MS-18	1046	1612	2104	2752	3188	3716	5247	3.40800
J-MS-19	1033	1576	2057	2684	3117	3641	5104	3.87900
J-MS-19+TR	2431	3786	4909	6506	7625	9015	12332	9.70100
J-MS-19A+R03	1036	1576	2058	2696	3133	3658	5128	3.79000
J-MS-20	2429	3768	4879	6462	7573	8967	12289	9.80600
J-MS-R03-01	38	71	98	134	159	190	266	0.06400
J-MS-R03-02	35	65	91	124	147	176	248	0.06700
J-MS-R03-02+01	72	135	186	255	302	362	509	0.13100
J-MS-R03-03	117	220	305	418	495	594	835	0.21300
J-MS-R03-04	67	112	149	197	229	269	366	0.06100
J-MS-R03-04+03	159	292	407	553	654	782	1093	0.27400

Broken Arrow Creek Flood Mitigation

Existing Flow Rates (CFS)

HMS Junction	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year	Drainage Area, mi ²
J-MS-R03-05	196	360	493	674	801	959	1296	0.33000
J-MS-R03-06	196	330	450	612	730	830	1027	0.38200
J-MS-R04-01	63	107	141	187	217	255	348	0.06800
J-MS-R04-02	105	183	246	329	384	459	650	0.13600
J-MS-R04-03	191	323	428	565	658	774	1063	0.21500
J-TR-13	1375	2296	3082	4203	4997	5973	8289	4.23500
J-TR-13+R02	1614	2673	3607	4882	5796	6886	9499	5.09900
J-TR-14	1603	2631	3553	4797	5658	6699	9209	5.16900
J-TR-15	74	132	179	241	284	337	467	0.09600
J-TR-15+14	1610	2642	3568	4817	5681	6727	9246	5.26500
J-TR-16	1604	2636	3553	4781	5641	6682	9186	5.34900
J-TR-16+R01	1635	2684	3619	4872	5753	6816	9371	5.58000
J-TR-17	1624	2639	3557	4812	5689	6760	9312	5.64600
J-TR-18	50	94	130	177	210	252	353	0.07500
J-TR-18+17	1629	2646	3567	4825	5705	6778	9337	5.72100
J-TR-19	1634	2654	3577	4838	5722	6798	9366	5.82200
J-TR-R01-01	80	130	169	220	253	296	397	0.06300
J-TR-R01-02	87	149	199	264	309	366	505	0.14000
J-TR-R01-03	90	164	225	304	357	424	586	0.23100
J-TR-R02-09+R01	371	604	792	1037	1207	1423	2048	0.75800

Appendix-C Cost Estimates

PROBLEM AREA 1 - ALTERNATIVE 1 - BUY OUT 6 HOUSES + IMPROVE EAST 114TH ST TO 100 YR CAPACITY					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$100,000.00	\$100,000.00
2	UNCLASSIFIED EXCAVATION	CY	4500.0	\$15.00	\$67,500.00
3	BORROW	CY	12250.0	\$25.00	\$306,250.00
4	24' ROADWAY W/ 3' SHOULDERS	LF	1210.0	\$170.00	\$205,700.00
5	6-16'X12' RCB CONCRETE	CY	410.4	\$500.00	\$205,200.00
6	6-16'X12' RCB STEEL	LB	73974.0	\$2.00	\$147,948.00
7	6-16'X12' RCB HEADWALL CONCRETE	CY	677.2	\$500.00	\$338,600.00
8	6-16'X12' RCB HEADWALL STEEL	LB	78080.0	\$2.00	\$156,160.00
9	8-16'X11' RCB CONCRETE	CY	535.9	\$500.00	\$267,934.50
10	8-16'X11' RCB STEEL	LB	94555.8	\$2.00	\$189,111.64
11	8-16'X11' RCB HEADWALL CONCRETE	CY	815.4	\$500.00	\$407,709.00
12	8-16'X11' RCB HEADWALL STEEL	LB	87789.6	\$2.00	\$175,579.20
13	5-12'X10' RCB CONCRETE	CY	241.0	\$500.00	\$120,490.50
14	5-12'X10' RCB STEEL	LB	43426.7	\$2.00	\$86,853.36
15	5-12'X10' RCB HEADWALL CONCRETE	CY	370.1	\$500.00	\$185,036.00
16	5-12'X10' RCB HEADWALL STEEL	LB	44021.2	\$2.00	\$88,042.40
17	REMOVAL OF PAVEMENT	SY	2688.9	\$12.00	\$32,266.67
18	REMOVAL OF STRUCTURES	LS	1.0	\$75,000.00	\$75,000.00
Subtotal					\$3,155,381.26
25% Utility Relocation Contingency					\$788,845.32
Subtotal					\$3,944,226.58
15% Contingency					\$591,633.99
Grand Total					\$4,535,860.57

PROBLEM AREA 1 - ALTERNATIVE 2- IMPROVE EAST 114TH ST TO 10 YR CAPACITY					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$90,000.00	\$90,000.00
2	UNCLASSIFIED EXCAVATION	CY	2000.0	\$15.00	\$30,000.00
3	BORROW	CY	7650.0	\$25.00	\$191,250.00
4	24' ROADWAY W/ 3' SHOULDERS	LF	1150.0	\$170.00	\$195,500.00
5	4-12'X10' RCB CONCRETE	CY	201.6	\$500.00	\$100,800.00
6	4-12'X10' RCB STEEL	LB	32892.0	\$2.00	\$65,784.00
7	4-12'X10' RCB HEADWALL CONCRETE	CY	365.6	\$500.00	\$182,800.00
8	4-12'X10' RCB HEADWALL STEEL	LB	45880.0	\$2.00	\$91,760.00
9	4-12'X8' RCB CONCRETE	CY	188.4	\$500.00	\$94,200.00
10	4-12'X8' RCB STEEL	LB	28338.0	\$2.00	\$56,676.00
11	4-12'X8' RCB HEADWALL CONCRETE	CY	254.4	\$500.00	\$127,200.00
12	4-12'X8' RCB HEADWALL STEEL	LB	33040.0	\$2.00	\$66,080.00
13	10'X6' RCB CONCRETE	CY	41.1	\$500.00	\$20,550.00
14	10'X6' RCB STEEL	LB	7905.0	\$2.00	\$15,810.00
15	10'X6' RCB HEADWALL CONCRETE	CY	60.0	\$500.00	\$30,000.00
16	10'X6' RCB HEADWALL STEEL	LB	8980.0	\$2.00	\$17,960.00
17	REMOVAL OF PAVEMENT	SY	2555.6	\$12.00	\$30,666.67
18	REMOVAL OF STRUCTURES	LS	1.0	\$75,000.00	\$75,000.00
Subtotal					\$1,482,036.67
25% Utility Relocation Contingency					\$370,509.17
Subtotal					\$1,852,545.83
15% Contingency					\$277,881.88
Grand Total					\$2,130,427.71

PROBLEM AREA 1 - ALTERNATIVE 3- BUY OUT 6 HOUSES + EXTEND S 31ST STREET					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$150,000.00	\$150,000.00
2	CUT	CY	10000.0	\$15.00	\$150,000.00
3	FILL	CY	12000.0	\$15.00	\$180,000.00
4	24' ROADWAY W/ 3' SHOULDERS	LF	2650.0	\$170.00	\$450,500.00
5	10'X10' RCB CONCRETE	CY	66.8	\$500.00	\$33,400.00
6	10'X10' RCB STEEL	LB	12680.0	\$2.00	\$25,360.00
7	10'X10' RCB HEADWALL CONCRETE	CY	138.0	\$500.00	\$69,000.00
8	10'X10' RCB HEADWALL STEEL	LB	19040.0	\$2.00	\$38,080.00
9	REMOVAL OF PAVEMENT	SY	1000.0	\$12.00	\$12,000.00
10	REMOVAL OF STRUCTURES	LS	1.0	\$5,000.00	\$5,000.00
Subtotal					\$1,113,340.00
25% Utility Relocation Contingency					\$278,335.00
Subtotal					\$1,391,675.00
15% Contingency					\$208,751.25
Grand Total					\$1,600,426.25

PROBLEM AREA 1 - ALTERNATIVE 4- BUY OUT 6 HOUSES + NEW 100 YR BRIDGE ON EAST 115TH STREET					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$30,000.00	\$30,000.00
2	UNCLASSIFIED EXCAVATION	CY	2000.0	\$15.00	\$30,000.00
3	30' SPAN BRIDGE	LF	900.0	\$4,000.00	\$3,600,000.00
				Subtotal	\$3,660,000.00
				25% Utility Relocation Contingency	\$915,000.00
				Subtotal	\$4,575,000.00
				15% Contingency	\$686,250.00
				Grand Total	\$5,261,250.00

PROBLEM AREA 1 - ALTERNATIVE 5- NEW 10 YR BRIDGE ON EAST 115TH STREET					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$30,000.00	\$30,000.00
2	BORROW	CY	5000.0	\$25.00	\$125,000.00
3	24' ROADWAY W/ 3' SHOULDERS	LF	375.0	\$170.00	\$63,750.00
4	30' SPAN BRIDGE	LF	525.0	\$4,000.00	\$2,100,000.00
				Subtotal	\$2,318,750.00
				25% Utility Relocation Contingency	\$579,687.50
				Subtotal	\$2,898,437.50
				15% Contingency	\$434,765.63
				Grand Total	\$3,333,203.13

PROBLEM AREA 1 - ALTERNATIVE 6- DETENTION FACILITY IN BROKEN ARROW CREEK TRIBUTARY					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$500,000.00	\$500,000.00
2	CUT	CY	1144050.0	\$15.00	\$17,160,750.00
3	FILL	CY	31500.0	\$15.00	\$472,500.00
4	OUTLET STRUCTURE	LS	1.0	\$150,000.00	\$150,000.00
Subtotal					\$18,283,250.00
25% Utility Relocation Contingency					\$4,570,812.50
Subtotal					\$22,854,062.50
15% Contingency					\$3,428,109.38
Grand Total					\$26,282,171.88

PROBLEM AREA 1 - ALTERNATIVE 7- DETENTION FACILITY IN BROKEN ARROW CREEK TRIBUTARY AND MAINSTREAM					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	TRIBUTARY CLEARING AND GRUBBING	LS	1.0	\$500,000.00	\$500,000.00
2	TRIBUTARY CUT	CY	1144050.0	\$15.00	\$17,160,750.00
3	TRIBUTARY FILL	CY	31500.0	\$15.00	\$472,500.00
4	TRIBUTARY OUTLET STRUCTURE	LS	1.0	\$150,000.00	\$150,000.00
5	MAINSTREAM CLEARING AND GRUBBING	LS	1.0	\$500,000.00	\$500,000.00
6	MAINSTREAM CUT	CY	922267.0	\$15.00	\$13,834,005.00
7	MAINSTREAM FILL	CY	10000.0	\$15.00	\$150,000.00
8	MAINSTREAM OUTLET STRUCTURE	LS	1	\$100,000.00	\$100,000.00
Subtotal					\$32,867,255.00
25% Utility Relocation Contingency					\$8,216,813.75
Subtotal					\$41,084,068.75
15% Contingency					\$6,162,610.31
Grand Total					\$47,246,679.06

PROBLEM AREA 2 - ALTERNATIVE 1- DETENTION FACILITY IN BROKEN ARROW CREK MAINSTREAM					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$500,000.00	\$500,000.00
2	CUT	CY	922267.0	\$15.00	\$13,834,005.00
3	FILL	CY	10000.0	\$15.00	\$150,000.00
4	OUTLET STRUCTURE	LS	1.0	\$100,000.00	\$100,000.00
Subtotal					\$14,584,005.00
25% Utility Relocation Contingency					\$3,646,001.25
Subtotal					\$18,230,006.25
15% Contingency					\$2,734,500.94
Grand Total					\$20,964,507.19

PROBLEM AREA 3 - ALTERNATIVE 1 - 19310 EAST 114TH STREET (NEW SMD AND CROSS DRAIN)					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$1,000.00	\$1,000.00
2	UNCLASSIFIED EXCAVATION	CY	10.0	\$15.00	\$150.00
3	TRENCHING	CY	23.0	\$15.00	\$345.18
4	ODOT SMD TYPE I	EA	1.0	\$3,000.00	\$3,000.00
5	18" RCP	LF	49.0	\$60.00	\$2,940.00
6	CONNECT TO EXISTING SMD	EA	1.0	\$1,000.00	\$1,000.00
7	STANDARD BEDDING	CY	13.4	\$150.00	\$2,013.90
8	SODDING	SY	48.3	\$5.00	\$241.67
9	PAVEMENT PATCHING	SY	7.0	\$100.00	\$704.44
Subtotal					\$11,395.19
25% Utility Relocation Contingency					\$2,848.80
Subtotal					\$14,243.99
15% Contingency					\$2,136.60
Grand Total					\$16,380.58

PROBLEM AREA 8 - ALTERNATIVE 1 - 10407 SOUTH 194TH EAST AVENUE (6'X3' RCB W/ 2.5' DEEP EAST CHANNEL) (100-yr)					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$15,000.00	\$15,000.00
2	UNCLASSIFIED EXCAVATION	CY	500.0	\$15.00	\$7,500.00
3	6'X3' RCB	LF	32.0	\$650.00	\$20,800.00
4	6'X3' RCB HEADWALL	EA	2.0	\$7,800.00	\$15,600.00
5	24' ROADWAY W/ 3' SHOULDERS	LF	330.0	\$170.00	\$56,100.00
6	SODDING	SY	800.0	\$5.00	\$4,000.00
Subtotal					\$119,000.00
25% Utility Relocation Contingency					\$29,750.00
Subtotal					\$148,750.00
15% Contingency					\$22,312.50
Grand Total					\$171,062.50

PROBLEM AREA 8 - ALTERNATIVE 2 - 10407 SOUTH 194TH EAST AVENUE (2-30" ELL RCP W/ 2' DEEP EAST CHANNEL)					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$15,000.00	\$15,000.00
2	UNCLASSIFIED EXCAVATION	CY	450.0	\$15.00	\$6,750.00
3	2-30" ELLIPTICAL RCP	LF	32.0	\$440.00	\$14,080.00
4	6'X3' RCB HEADWALL	EA	2.0	\$7,500.00	\$15,000.00
5	PAVEMENT PATCHING	SY	30.0	\$100.00	\$3,000.00
6	SODDING	SY	940.0	\$5.00	\$4,700.00
Subtotal					\$58,530.00
25% Utility Relocation Contingency					\$14,632.50
Subtotal					\$73,162.50
15% Contingency					\$10,974.38
Grand Total					\$84,136.88

PROBLEM AREA 9 - ALTERNATIVE 1 - 10313 SOUTH 193RD EAST AVE (1.7' DEEP WEST AND NORTH CHANNEL)					
ITEM	DESCRIPTION	UNIT	TOTAL	UNIT PRICE	TOTAL COST
1	CLEARING AND GRUBBING	LS	1.0	\$25,000.00	\$25,000.00
2	UNCLASSIFIED EXCAVATION	CY	1100.0	\$15.00	\$16,500.00
3	FENCING	LF	2350.0	\$25.00	\$58,750.00
4	SODDING	SY	2700.0	\$5.00	\$13,500.00
				Subtotal	\$113,750.00
				25% Utility Relocation Contingency	\$28,437.50
				Subtotal	\$142,187.50
				15% Contingency	\$21,328.13
				Grand Total	\$163,515.63