0 375 750 1,500
Feet

Aerial Photography: 2007
Coordinate System: Oklahoma State Plane, South Zone
Horizontal Datum: NAD 1983
Vertical Datum: NAVD 1988

Legend

City Boundary
Existing Drainage Easement

Stream Centerlines
Level 1 and 2 (Detailed)
Level 3 and 4 (General)

Floodplains
100-year Baseline
100-year Solution

Buildings in Floodplain
100-year Baseline
100-year Solution

Recommended Solutions
Road Crossing Upgrade
Property Buyouts
Floodwall
Channel Stabilization
Channel Improvements
Storm Sewer Improvements
Storm Water Detention

NORMAN

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Storm Water Master Plan

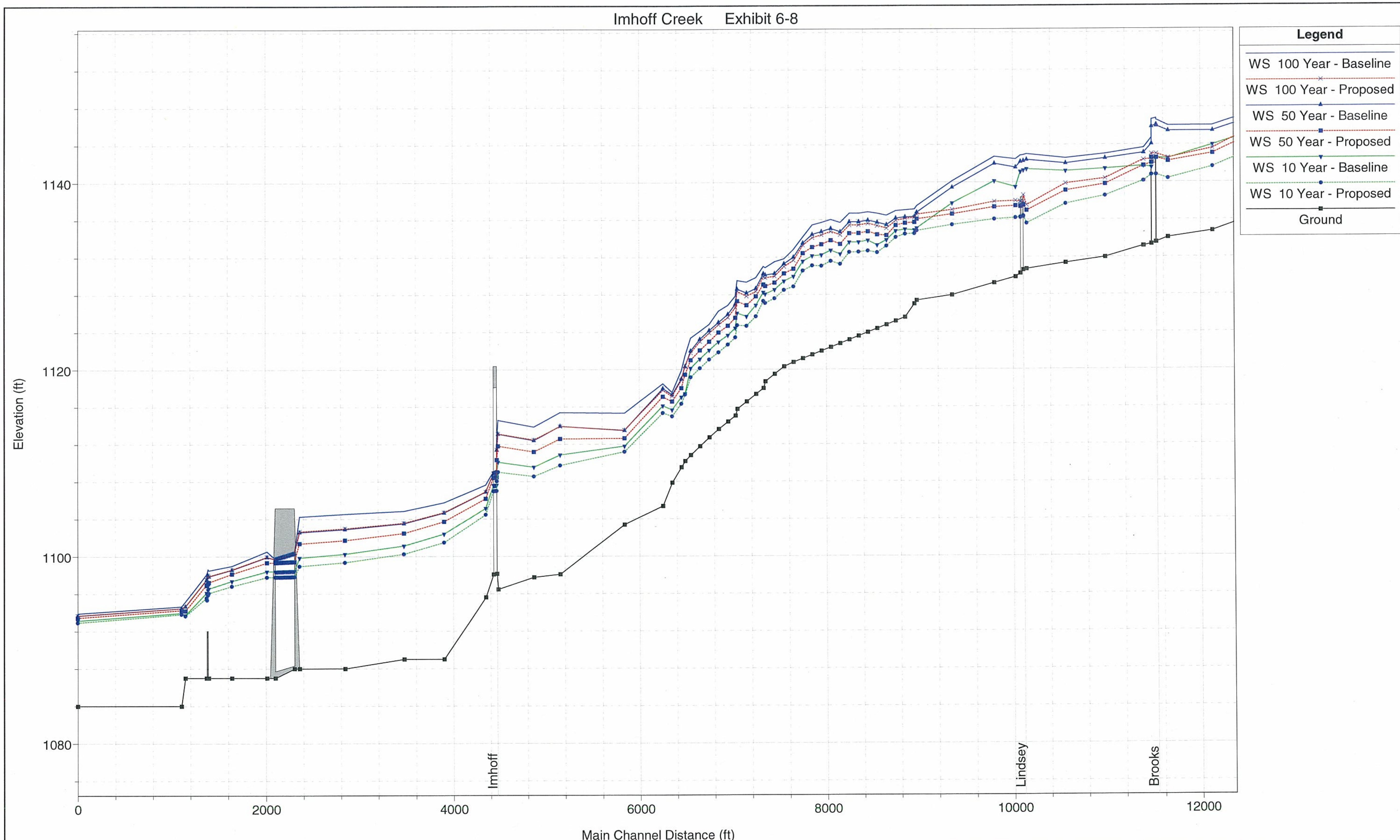
Exhibit 6-7b

Baseline Floodplain and Recommended Solutions Overview Ihmhoff Creek & Canadian River Trib.

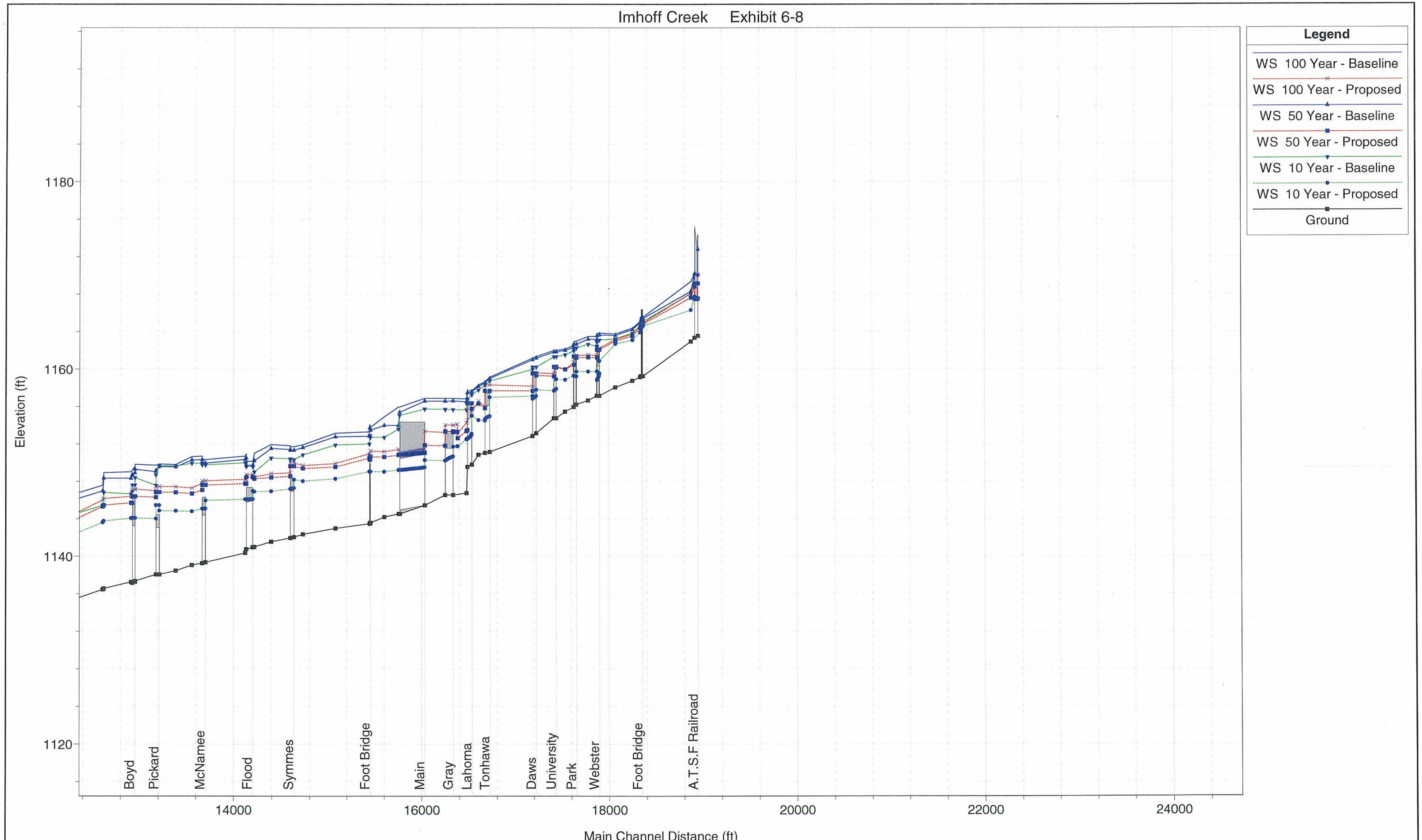
Sheet 1 of 1

Job No.: 044194100	Date: 12-11-08	Scale: 1 inch = 750 Feet

File: W:/WR/proj/441941_Norman/Report/Figures/Imhoff_and_Canadian_Riv.mxd



1 in Horiz. = 1000 ft 1 in Vert. = 10 ft



1 in Horiz. = 1000 ft 1 in Vert. = 10 ft

- Facility side slopes will be between 3:1 and 4:1 (H:V) and grassed lined
- Top of facility at elevation 1171
- Outfall through 36-inch RCP at southeast corner of the facility
- Overflow (50 ft weir in water tank area) to modified existing channel

- IC-4: Secondary detention areas (approximately 2.0 acres) in open areas (only) bounded by Webster Avenue, University Avenue, and the Imhoff Creek channel
  - Inflow from primary detention area through a 330-ft-long, 36-inch RCP at northeast portion of detention area
  - Two houses to be acquired and removed near intersection of Park and Daws
  - Abandon and remove Park Avenue from its intersection with Webster Avenue to Daws Street (approximately 350 ft in length)
  - Detention area to generally slope (1%) toward the southwest
  - Facility side slopes will be between 3:1 and 4:1 (H:V) and grassed lined
  - Top of facility at elevation 1163
  - Outflow through 36-inch RCP, 50 ft long, with backflow preventing flapgate
  - Overflow over 50-ft-long weir near Park Street intersection with Imhoff Creek
- IC-4A: Additional detention north of Acres Street
  - Area that drains to IC-4A is 352 acres
  - Includes all of IC-4 detention facility components
  - Large secondary detention area (6.5 acres)
  - Inflow from local subareas along BNSF railroad ditch plus intercepted flow piped from the intersection of University Avenue and Highland Street
  - Pond bottom at 1% slope to the southeast
  - Concrete pilot channel along eastern edge of facility
  - Facility side slopes will be between 3:1 and 4:1 (H:V) and grassed lined
  - Outflow through a 24-inch RCP, 200-ft length
  - Overflow via a 100 ft weir at elevation 1,175 ft into the ditch adjacent to the railroad
  - Top of facility at elevation 1,176 ft

IC-3 constitutes another very significant solution for stream flooding in the middle and upper reaches with costs of almost $21 million. As mentioned previously this long and complex solution has been divided into eight sub-reach solutions (IC-3A through IC-3H) that collectively extend from about 1,200 ft downstream of Lindsey Street upstream to Webster Avenue near Andrews Park. The IC-3 modifications include all bridges/culverts and the entire length of creek channel. The IC-3 solution and its impacts on the water surface elevations can best be described by looking at it on a sub-reach basis as discussed below and as shown in Exhibits 6-7a and 6-8.

Recreation and flood control in park setting

For channel improvements proposed for the IC-3 sub-reach solutions, space to make the improvements is a significant consideration due to the associated costs to acquire and clear such space needed. Although targeted protection for road crossings varied between the 10-, 50-, and 100-year levels, the channel improvements for all of the sub-reaches targeted the 10-year flooding event since protection for larger events was judged to require too much property acquisition and utility adjustments. Additionally, there are serious property owner inconveniences and difficulties associated with acquiring the related property in terms of easements or right-of-way. These difficulties include the time, effort, and costs to negotiate settlement terms, at times, with reluctant property owners, possible displacement of residents, locating alternative housing, possible negative public perception, and disruption of businesses among other things. The difficulties must be weighed against the benefits which include things such as citizen safety, property protection from flooding, and traffic improvements during flooding periods.

Due to these space limitation concerns, improvements requiring the smallest footprint such as a WPA-type mortared wall with a concrete bottom were selected for detailed analysis and cost estimating. The use of a more natural (rock, earth) channel design, which typically requires a relatively larger footprint, constitutes a possible design alternative even though space requirements would be greater and costs could be somewhat higher compared to an enlarged WPA-type channel. Further, the proposed channel enlargement in the affected sub-reaches having the existing WPA channel will consist of removal of one or both sides of the channel bank (side various depending on location), widening along that side of the channel, and reconstruction of a similar, mortared rock wall (unless an alternative natural channel solution with rock is determined to be preferable during project design). In some locations, the channel bottom will be saw-cut at a safe distance of any remaining wall and repaired and extended to fit the new channel. In providing cost estimates it was assumed that 75% of the WPA channel walls would be replaced and the remaining 25% would be preserved. Preserving certain select portions of these channel walls is proposed due to their historical nature, the concern that replacing certain sections would possibly impact existing infrastructure and/or homes, as well as the fact that certain portions of the existing walls appear stable and are functioning well. During final design, value engineering should be performed to insure that any of the retained sections of the existing WPA channel walls are structurally sound. Final selection of the channel type should be made during the project engineering design process. Channel design options are discussed further in Section 6.2.

Finally, there is considerable interest in the possibility of advancing the idea of acquiring a much larger portion of the flood prone area, such as the FEMA floodway, along the IC-3 reach. The prevailing thought of this idea would be to expand the property buyout approach to include large numbers of the most flood prone structures in this reach. Further investigation beyond the scope of this SWMP will be required to fully understand the costs and benefits of this approach.

Due to the numerous changes in channel improvements within the eight sub-reaches, the HEC-RAS stationing is used below in certain instances to describe the beginnings and ends of the improvements.

IC-3A (From near the Elmwood Drive dead end upstream, about 1,200 ft downstream of Lindsey St., to near Madison St. dead end, including a road crossing upgrade at W. Lindsey St.)

The IC-3A solution calls for replacing the existing culvert system (three 8-x-6-ft RCBs) at Lindsey Street with a 20 inch depth box beam bridge consisting of two 30 ft spans, a middle bent, a concrete bottom, and a raised roadway (2 ft) which, collectively, prevents overtopping for the 100-year baseline event. The raised road profile requires 375 ft of reconstructed roadway and five reconstructed driveways.

The proposed channel improvements in this sub-reach vary according to the following:

- Road crossing HEC-RAS stations:
  - Lindsey Street – 10944
- HEC-RAS stations 9700 to 10650:
  - trapezoidal, 15 ft channel bottom width
  - 1.5:1 side slopes
  - articulated block lining
  - overbank benching
- 10650 to 10994:
  - channel transitions into a rectangular channel downstream of Lindsey Street
  - 40 ft bottom width at 10876, further transitions to 60 ft at Lindsey Street bridge
  - vertical side slopes
  - articulated block lining on channel bottom except concrete lined under proposed Lindsey Street bridge
  - overbank benching from 10650 to 10876
- 10994 to 11320 (end of IC-3A sub-reach):
  - trapezoidal, 20 ft channel bottom width
  - 1.5:1 side slopes

As discussed above, typical cross sections for various proposed channel designs is presented in Section 6.2. The bridge and channel improvements remove 11 of the 14 structures (buildings) from the baseline floodplain.

Stream conveyance improvements and stabilization in urban setting

IC-3B (From near the Madison St. dead end upstream to a location about 150 ft downstream of W. Boyd Street., including a crossing at W. Brooks Street)

The IC-3B solution involves replacing the existing concrete slab bridge at Brooks Street with a 20-inch-depth box beam bridge consisting of one 50-ft span, a concrete lined trapezoidal cross section through the bridge with a 20 ft bottom width and 4:1 side slopes which prevents overtopping for the 10-year event.

The proposed channel improvements are:

- Road crossing HEC-RAS stations:
  - Brooks Street – 12351
- 11320 to 12980
  - trapezoidal, 20 ft channel bottom width
  - 1.5:1 side slopes

- 12980 to 13637
  - transitions from trapezoidal channel (20 ft bottom width, 1.5:1 side slopes) to rectangular channel, 40 ft channel bottom width and vertical side slopes at 13637
  - articulated block lining used from 12980 to 13458
  - at 13458, bottom width at 30 ft and 1:1 side slopes
  - concrete bottom and sides used from 13458 to 13637

The bridge and channel improvements remove 19 of the 32 structures (homes, businesses) from the baseline floodplain.

IC-3C (From a location about 150 ft downstream of W. Boyd St. upstream to just below McNamee St., including road crossing upgrades to W. Boyd Street and S. Pickard Ave.)

IC-3C includes replacing the existing slab bridge at Boyd Street with a 20-inch-depth box beam bridge consisting of one 50-ft span, concrete-lined bottom, and the roadway being raised by 1 ft. Raising the roadway elevation results in street reconstruction of 375 ft along Boyd Street and 550 ft along Pickard Avenue. Five driveway modifications will be required along Boyd Street and four will be required along Pickard Avenue. Proposed modifications also call for Pickard Avenue's existing slab bridge to be replaced with a four 10-x-6-ft RCB culvert system. The Pickard Avenue expansion will primarily occur on the right side of the channel which will expand to 43 ft to accommodate the culvert system. Pickard's top of road will be raised to approximately 1,145.1 ft elevation to accommodate the culvert system and local roadway work. These bridge improvements prevent overtopping for 50-year flood event at Boyd Street and for the 10-year event for Pickard Avenue.

The proposed channel throughout this entire reach will be expanded to a bottom width of 40 ft, except at road crossings, with a concrete bottom and vertical side slopes constructed of mortared rock in WPA style. The bridge, culvert, and channel improvements remove 6 of the 13 structures (buildings) from the baseline floodplain.

IC-3D (From just below McNamee St. upstream to just upstream of Symmes St., including road crossing upgrades to McNamee St., S. Flood Ave., and W. Symmes St.)

This sub-reach solution involves replacing the existing road crossing openings at McNamee Street with four 10-x-6-ft RCBs, Flood Avenue with three 10-x-6-ft RCBs, and Symmes Street three 10-x-6-ft RCBs which accomplishes 10-year overtopping protection at all three locations. For the McNamee Street crossing, the expansion will occur primarily occur on the right side of the channel, which will expand to 43 ft to accommodate the RCBs. The top of road will be increased to approximately elevation 1,146.5, which will require the reconstruction of approximately 205 ft of the roadway (transition to existing intersection with Pickard) and will impact one or two driveways and may impact Lions Park sidewalks adjacent to the construction. For the Flood Avenue crossing area, the expansion will be to the right side of the channel and the section through the bridge will have a 32 ft bottom width in order to accommodate the RCBs. The top of road elevation will also be raised by 1 ft from 1,147 ft to 1,148 ft elevation. This raising of the road will require the reconstruction of approximately 170 ft along Flood Avenue which will impact three to four driveways. For the Symmes Street crossing, the expansion will be to both sides of the channel and the section through the bridge will have a 32 ft bottom width in order to accommodate the RCBs. The top of road elevation will also be raised by 1 ft from 1,148 ft to 1,149 ft elevation. This raising of the road will require the reconstruction of approximately 110 ft along Symmes Street impacting two driveways.

The proposed channel throughout this entire reach will be expanded to a bottom width of 30 ft with vertical side slopes constructed of mortared rock in WPA style. There are proposed buyouts upstream of Flood Avenue (4 structures) at a significant cost of almost $800,000 out of the total sub-reach cost of near $3.2 million. The culvert and channel improvements remove 17 of the 29 structures (buildings) from the baseline floodplain.

IC-3E (From just upstream of W. Symmes St. upstream to just below Main St.)

This sub-reach solution does not include any bridges or culverts. The proposed channel throughout this entire reach will be expanded to a bottom width of 30 ft with vertical side slopes constructed of mortared rock in WPA style. This solution also calls for replacement of a school footbridge at station 16300 with a new bridge. There are 12 proposed buyouts in this sub-reach at a cost of almost $2.2 million out of a cost of more than $3.4 million. The replacement of the school bridge and channel improvements remove 21 of the 25 structures (buildings) from the baseline floodplain.

IC-3F (A Main St. road crossing upgrade plus a short length of adjacent channel improvements)

The IC-3F solution consists of upgrading the Main Street crossing that presently has a 12-x-5.5-ft slab bridge opening to a three 10-x-6-ft RCB culvert system. In order to correctly reflect the flooding improvements associated with this solution, certain modeling actions were required. The baseline model developed from the previous LOMR models includes an abrupt 2.8-ft drop in the channel bottom immediately downstream of the Lahoma Avenue crossing. This drop is not reflected in the new, detailed topography for the City of Norman or in the photographs taken of the stream during this study. The topographic data does show a drop of approximately 2-ft between the downstream end of the Main culverts and the downstream end of the alley crossing immediately adjacent to the Main Street culverts. It appears that this drop was modeled in the wrong location in the previous LOMR models. For the proposed solution, it was assumed that the channel would be lowered from the alley crossing to just upstream of Gray Street to roughly correspond to the situation reflected in the baseline model. However, the drop was moved away from the downstream face of Lahoma Avenue in order to smooth out the impacts of the drop through critical depth caused by the abrupt change in the bottom elevation of the channel. Cross sections 17225 and 17230 were added to the model in order to reflect the new location of the drop. The approximately 2-ft drop in the channel is necessary in order to pass the 100-year baseline flows at Main Street without overtopping. Without the additional vertical clearance, the crossing would have to be made wider than is realistically possible given the presence of businesses immediately adjacent to the Main Street culverts.

IC-3G (From just above Main St. upstream to just above W. Tonhawa St., including road crossing upgrades to W. Gray St., N. Lahoma St., and W. Tonhawa St.)

IC-3G calls for constructing new culvert systems at W. Gray Street (three 9-x-5-ft RCBs), N. Lahoma Street (three 9-x-5-ft RCBs), and W. Tonhawa Street (three 7-x-5-ft RCBs) which provides overtopping protection for the 10-year flood at all three crossings. The Gray Street upgrade includes the lowered channel bottom discussed above for the Main Street upgrade and does not require raising the roadway. The proposed channel will be expanded according to:

- Road crossing HEC-RAS stations:
- W. Gray Street – 17140
- N. Lahoma Avenue – 17357
- W. Tonhawa Street – 17559
- 16970 to 17370
- rectangular, 30 ft bottom width
- vertical side slopes, mortared rock walls
- 17370 to 17574
- rectangular, 25 ft bottom width
- vertical side slopes, mortared rock walls

Proposed buyouts in this sub-reach include three structures upstream of W. Gray Street that cost about $316,000 whereas the total costs are almost $1.7 million. The culvert and channel improvements remove 12 of the 22 structures (buildings) from the baseline floodplain.

IC-3H (From just above W. Tonhawa St. upstream to just above N. Webster Ave., including road crossing upgrades at W. Daws St., N. University Blvd., and N. Webster Ave. (N. Park Ave. crossing upgrade not included as this street is assumed removed as part of the Andrews Park storm water detention modifications)

Solution IC-3H calls for replacing the existing bridge slabs at W. Daws Street (three 7-x-4-ft RCBs), N. University Boulevard (three 7-x-4-ft RCBs), and N. Webster Avenue (three 7-x-3-ft RCBs). The proposed rectangular channel will be expanded to a bottom width of 25 ft throughout the entire sub-reach. The sides shall be constructed of mortared rock in WPA style. Proposed buyouts in this sub-reach include two structures that cost about $157,000 out of the total costs of almost $1.5 million. The culvert and channel improvements remove 48 of the 64 structures (buildings) from the baseline floodplain.

Solutions to stabilize stream erosion problems in lower Imhoff Creek extend for over 5,000 ft and are substantial. Two solutions (IC-1 and IC-2) have been developed and are somewhat similar as both are aimed at stabilizing a significant stream degradation process that includes down cutting of the streambed, widening of the creek between its banks

Stable stream section using low-flow channel and vegetated side slopes

through ongoing bank failure and collapse, destruction of numerous trees, backyard fences, as well as the loss of usable property. The stabilization solutions are based on using natural materials, laying back slopes where possible, and adding mechanically stabilized earth (MSE) structures in other locations where there are space limitations. In an effort to save costs, the conceptual solutions basically try to stabilize the eroded stream cross sections in their present condition although excavation will be required in certain locations. As shown in Exhibit 6-7a, Solution IC-1 begins approximately 800 ft downstream of Highway 9, upstream of the creek's confluence with the Canadian River, and extends upstream to SH 9. IC-2 begins at the highway and extends upstream to a point about 2,000 ft upstream of Imhoff Road. Section 6.2 provides a discussion of these recommended stabilization techniques including typical design sections.

As outlined in Section 5 and generally located in Exhibit 6-7b, the local area in the vicinity of the Lindsey Street and McGee Drive intersection, including a large part of the west-central Imhoff Creek watershed area, represents one of the worst localized flooding problems in Norman. The IC-5 solution, herein referred to as the "West Central Imhoff Creek Watershed Improvements," was developed to a 10-year flood level and will alleviate this problem for all but very large storm events. The 10-year protection level was selected instead of a higher level such as the 100-year level in order to generally balance the costs of the required improvements with benefits received. Since the flooding problem occurs frequently, the main goal was to stop the frequent flooding while also providing significant, though not total, protection during even large events such as a 100-year event (1% annual chance). Additionally, for events greater than the 10-year event, some additional drainage relief is provided by a relatively new system referred to as the Phase I Baldischwiler system that drains local runoff to Imhoff Creek through a concrete channel located just south of the Lindsey-McGee intersection that connects to a large storm sewer system that flows to the creek, outfalling approximately 1,300 ft south of Lindsey Street. IC-5 improvements discussed here would take the place of Phases II and III as proposed in the Baldischwiler (1997) and Baldischwiler (2001) reports previously developed for the City of Norman to alleviate the Lindsey-McGee flooding problem.

As presented in Figure 6-1, which provides system sizes, the IC-5 solution basically provides protection to this west-central area of the Imhoff Creek watershed by collecting storm water into a large storm sewer system that begins at Camden and Rosedale in its north subsystem, extends south along Rosedale, then west to McGee, continues south along McGee to Lindsey, picks up flows from the eastern subsystem in the intersection area, then flows from the Lindsey-McGee intersection westward along Lindsey to its intersection with Murphy, goes south along Murphy to Briggs, heads west along Briggs to a drainage channel adjacent to IH 35, then flows south in the drainage channel to SH 9, passes under SH 9, and finally completes the diversion to the Canadian River just downstream of the IH 35 crossing of the river. A key IC-5 subsystem begins at the junction with a local neighborhood storm drain system located approximately 800 ft east of the Lindsey-McGee intersection, flows westward along Lindsey to the Lindsey-McGee intersection where it joins the north subsystem in the intersection area. The total amount of area diverted from Imhoff Creek amounts to almost 310 acres. Many local residents are convinced that at least a portion of this 310-acre area was previously diverted to Imhoff Creek from Merkle Creek as the area was developed. Another significant aspect of the IC-5 diversion is that it removes a significant amount of storm water from lower Imhoff Creek where serious stream flooding and erosion problems exist. Finally, the IC-5 solution proposes a separate new storm drain system that collects storm water along Wylie Avenue then along Lindsey Street, ultimately extending to Imhoff Creek near the Lindsey Street creek crossing as shown in Exhibit 6-7b and Figure 6-1.

Stream protection along steep bank

Little River Mainstem

Two solutions (LR-1 and LR-2) have been conceptually developed along the Little River mainstem. These two solutions are located in Exhibit 6-9 with pertinent information provided in Table 6-2. The LR-2 solution alleviates a stream flooding problem by acquiring a mobile home park area that is flooded by medium and large events which endangers residents and causes recurring damage. A majority of the units or lots are in the baseline (100-year) floodplain although a few may be outside of this floodplain. It is realized that it is difficult to displace residents as they will be required to find another home but their safety is also of concern.

The LR-1 solution addresses a severe stream erosion problem located about 2,000 ft upstream of 12th Avenue NW. The stream stabilization improvements will protect the river bank from the erosion that is occurring along about 350 ft of river. This solution will also protect a residence that will soon be threatened by the erosion.

No localized problems were identified in the watershed.

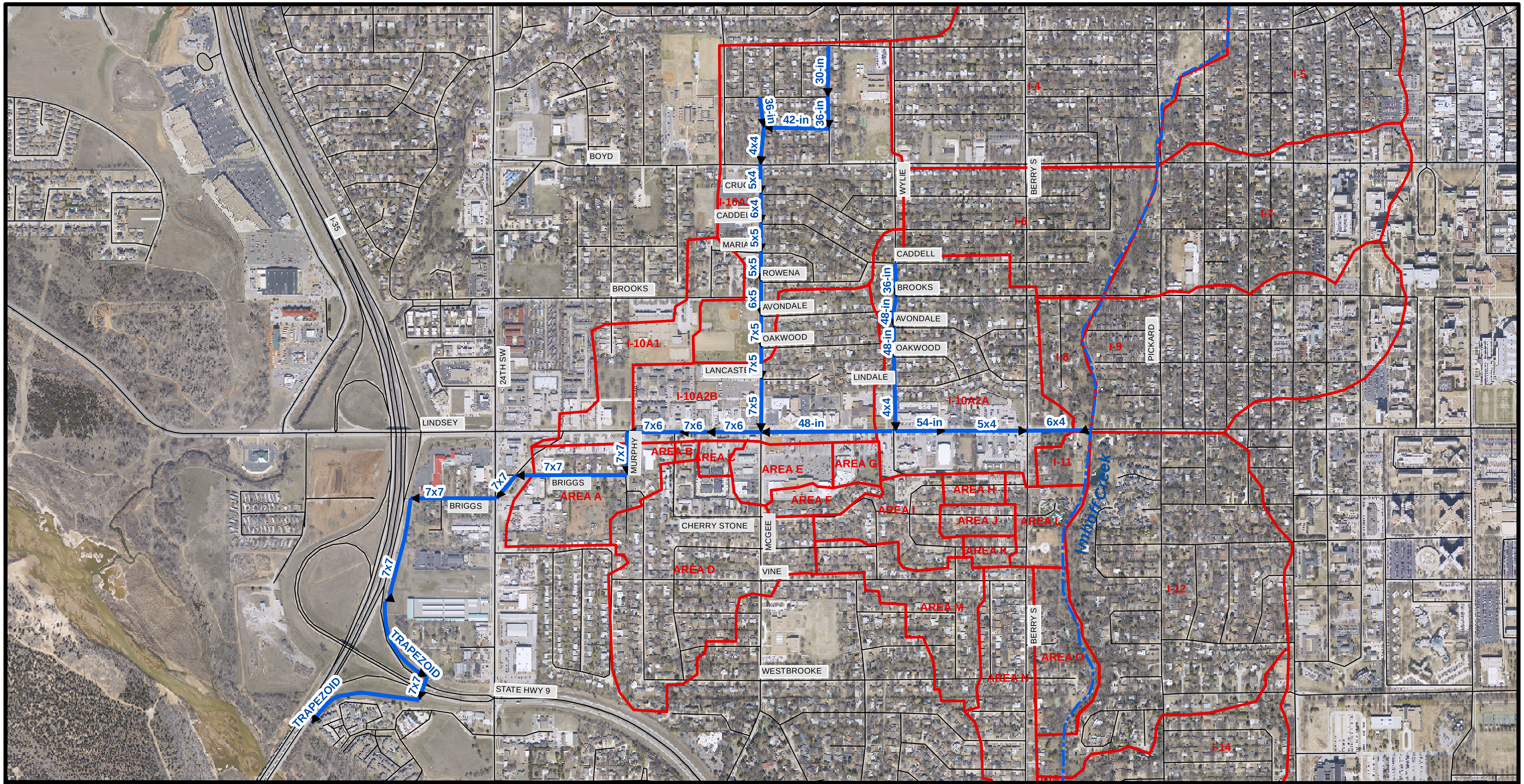
Little River – Tributary G

The TGLR-1 solution outlined in Table 6-2 and shown in Exhibits 6-11 and 6-12 provides protection for a stream flooding problem at Franklin Street located west of the IH 35 highway corridor. The solution will significantly enlarge the undersized road crossing opening from the existing 10.5-x-7 ft corrugated metal pipe (CMP) to five 10-x-10-ft RCBs. The much larger culvert system was required to offset the upstream backwater effects associated with raising the local roadway in the crossing area by approximately 1.5 ft. The roadway was raised to be above the flood levels caused by the capacity limitations of the IH 35 culverts. Preliminary and final design should further investigate additional downstream improvements to the IH 35 culvert system to reduce flood levels in the Franklin Street area.

No stream erosion or localized problems were identified in the watershed.

Little River – Woodcrest Creek

As shown in Table 6-2 and Exhibits 6-13 and 6-14, the solutions in the Woodcrest Creek watershed include a proposed storm water detention facility on the creek upstream of E. Rock Creek Road (WC-1A), channel improvements downstream of Sequoyah Trail (WC-1B), a provisional upgrade to the culvert opening for Sequoyah Trail (WC-2) to be included only if WC-1A is not built, and stream erosion protection south (upstream) of Sequoyah Trail (WC-3). These improvements cost approximately $3.3 million and are needed to address the watershed's problems that include 20 homes in the baseline (100-year) floodplain footprint, two road crossings that flood (Sequoyah Trail and Nantucket Road), and a stream erosion location. The E. Rock Creek Road crossing was initially considered a problem but an ongoing improvement project and the WC-1A detention facility will alleviate this problem. Again, the WC-2 upgrade to Sequoyah Trail will not be needed if the WC-1A facility, or equal, is built. The WC-1A detention facility impacts the other remaining stream flooding solution (WC-1B) as modeling indicated that it could reduce 100-year baseline peak flows at its discharge point above E. Rock Creek Road from 2,050 cfs to a



0 600 1,200 2,400 Feet

Aerial Photography: 2007
Coordinate System: Oklahoma State Plane, South Zone
Horizontal Datum: NAD 1983
Vertical Datum: NAVD 1988

Legend

- Storm Drainage Improvements
- Imhoff Creek
- Imhoff Creek Subbasins
- Road Centerlines

PBSJ

Figure 6-1

West-Central Imhoff Creek Watershed Drainage Improvements (10-Year Design)

Job No.: 044194100	Date: 2-16-09	1 inch equals 1,000 feet

File: W:/WR/proj/441941_Norman/Report/Figures/Imhoff_Lindsey-McGee-10yr.mxd