Appendix A

2005 DMP Report Sections not Superseded by this 2011 DMP

DRAINAGE MASTER PLAN
2005

Prepared for:

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DRAINAGE MASTER PLAN STUDY REPORT

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Appendix A.1

General Provisions
(Section 3 of 2005 DMP)

3.0 GENERAL PROVISIONS

3.1 STORM WATER MANAGEMENT

To effectively control the problems of urban storm water runoff, the City of Killeen needs to adopt a comprehensive integrated approach to storm water management through a storm water management plan. This approach must link storm water quantity control with water quality protection, protection of streambanks and riparian corridors, floodplain management, habitat preservation and restoration, and use of storm water facilities for multiple purposes. The purpose of a storm water management plan is to:

- Minimize adverse impacts of storm water runoff within the City of Killeen
- Meet state and federal requirements
- Ensure that the City of Killeen's priorities and needs are being met with new development and re-development

To establish and sustain a functional management plan, the storm water management plan must include:

- A system baseline study
- Adequate legal authority
- Performance standards for development
- Design assistance and guidance
- Program funding and staffing
- Commitment to enforcement
- Public education and involvement
- A plan for system improvement
- A plan for system maintenance

3.2 FLOOD DAMAGE PREVENTION

Floodplain management is the primary tool used to reduce flood damage within the City of Killeen. This involves designating flood-prone areas and limiting their uses to those compatible with the risk. Since areas of residential and commercial development already exist within the floodplain, an active response is required to reduce potential flood damage, as addressed in the major and minor capital improvement programs. Floodplain management and restrictions on future development within the floodplain will also prevent future flood damage in developing areas. Review and approval of drainage plans for new development must be evaluated to

ensure the protection of public health, safety, and general welfare and to minimize public and private losses due to flood conditions.

3.3 LAND DEVELOPMENT

New development that is designed, constructed, maintained, and regulated effectively will improve quality of life from an economic, aesthetic, social, and recreational perspective. However, new development impacts the environment and, in particular, the drainage system and those impacts must be addressed before development is underway. When land is developed, the hydrology is disrupted and altered because clearing and grading removes vegetation that intercepts, slows, and returns rainfall to the air through evaporation and transpiration. Development also replaces topsoil with impervious cover and eliminates or significantly reduces the amount of rainfall that infiltrates, so rainfall that once seeped into the ground now runs off the surface rapidly and through the downstream drainage system.

Development not only affects the quantity of storm water runoff but also the quality and increases both the concentration and types of pollutants carried by runoff. As storm water flows over paved surfaces and other impervious cover, it lifts and transports a variety of contaminants and pollutants to downstream water bodies. The loss of vegetation and topsoil also removes a valuable filtering mechanism for storm water runoff. The cumulative impact of development and urban activities and the resultant changes to storm water quantity and quality control the integrity and usability of the water bodies within the City of Killeen.

3.4 DRAINAGE SYSTEM OPERATION AND MAINTENANCE

An essential component of any storm water management program is the ongoing operation and maintenance of the various components of the storm water drainage system. Failure to provide effective maintenance can reduce the flood carrying capacity of the system and increase potential flood losses. Operation and maintenance must include an initial assessment of each stream segment to determine what is required to establish baseline conditions. Routine maintenance must be scheduled to periodically restore the reach to the baseline condition. Recommendations for the City of Killeen Drainage Master Plan are included in Section 10.0 of this report.

Appendix A.2

Drainage System Evaluation (Section 4 of 2005 DMP)

4.0 DRAINAGE SYSTEM EVALUATION

4.1 HISTORICAL RECORDS

Historical records of drainage-related issues and flood events are maintained by the City of Killeen Public Works Department and analyzed by the Drainage Utility program. Problem areas are documented by Drainage Utility personnel during on-site field visits and drainage system inspections. Inspections are initiated by either citizen complaints or at the request of City staff. Documentation is provided by an on-site field report detailing the nature of the problem and includes the location, date, photographs and remedies/suggestions to alleviate the problem. The information from the field report is entered into a flood events record database. This database was evaluated to assess drainage issues.

The flood event data was enhanced by a public information survey initiated by the City in October 2003. A public survey form was mailed to residents with their monthly water bills and posted on the City's website to solicit citizen input on flooding issues and drainage problems. The survey form contained a brief explanation of the need for additional data and a series of pertinent questions. Approximately 200 forms have been submitted to date. The Drainage Utility's database was updated to include drainage problems reported on the survey forms and flood event data collected through February 2004.

4.2 FIELD INVESTIGATION

Carter & Burgess, with Drainage Utility staff, performed a field investigation of reported drainage problem locations. The field investigation was conducted December 6th-8th, 2004. A photo inventory was compiled during the field investigation and is included in **Appendix H**, to this report.

4.3 PROBLEM CATEGORIES

Drainage problems can arise at any location that receives or conveys storm water: residential lots, parking lots, streets, gutters, flumes, creeks, man-made channels, ponds, and lakes. Drainage problems range from minor inconveniences to substantial flood damage or loss of life. The causes of drainage problems vary greatly and include but are not necessarily limited to:

- Over-grown vegetation
- High flow velocity
- Debris blockage
- Structure failure
- Undersized structure or inadequate design
- Inadequate construction methods
- Increased flows caused by upstream development
- Unauthorized changes to drainage paths
- Floodplain encroachment

Typical reported drainage problems in Killeen included street flooding, residential lot flooding, overflow of drainage channels, erosion in drainage channels, and overgrown vegetation in drainage ways. Reported drainage problems were reviewed and categorized based on available data into the following seven categories:

- Channel maintenance/ overgrown vegetation – Channel or drainage way is clogged with vegetative growth, blocking flow of water.
- Erosion – Channel or drainage way experiences high velocities that erode channel banks or other areas.
- Debris – Channel or drainage way clogged by trash or debris, blocking flow of water.
- Structure failure – Drainage structure has collapsed or failed and does not function properly.
- Under-sized structure/ inadequate design – Drainage structure is too small. Possible upstream development has increased flow to the drainage structure.
- Flood-prone location/ street flooding – Natural low area or flooding of street.
- Inadequate grading – Ponding water or runoff from adjacent property flows toward structure.

Categorizing reported drainage problems allows for identification of repeated problems and possible drainage system inadequacies. Identifying system inadequacies will allow for a systematic solution to correct many individual drainage problems rather than small solutions to fix individual reported problems.

The documented drainage problems were analyzed with respect to the frequency of reported incidents and geographic distribution. Results of these analyses are discussed in the following sections.

4.4 PROBLEM CATEGORY STATISTICS

Reported drainage problems were divided into the individual categories identified in Subsection 4.3, and the percentage of reported problems were calculated. **Table 4.1** illustrates the seven drainage problem categories, total number of events reported, and percentage of total events reported.

Table 4.1: Reported Drainage Problem, by Category

Category	Description	Number of Problems	Percentage of Total
1	Channel Maintenance – Vegetative	40	7.05
2	Erosion	22	3.88
3	Debris	67	11.81
4	Structure-Failure	9	1.59
5	Undersize Structure – Inadequate Design	56	9.88
6	Flood-Prone Location – Street Flooding	284	50.09
7	Inadequate Grading	89	15.70

Based on the percentage of reported incidents, Flood-Prone Location – Street Flooding is a major concern to Killeen residents. In fact, out of a total of 567 reported incidents, over fifty percent of reported drainage problems were categorized as Flood-Prone Location – Street Flooding (**Figure 4.1**).

This high figure could be attributed to the fact that the City of Killeen currently allows streets and roadways to be used for conveyance of storm water, making it one of the most highly visible and used parts of the City's drainage infrastructure. In contrast, a drainage event in an isolated area along the drainage system may not be noticed except by those living in the immediate area.

A moderate number (greater than 10 percent) of reported problems were attributed to Inadequate Grading, Undersized Structure-Inadequate Design, Debris, and Channel Maintenance-Vegetation. Less frequently reported were problems associated with Structure-Failure and Erosion, which comprised less than 5 percent of the total incidents in the database.

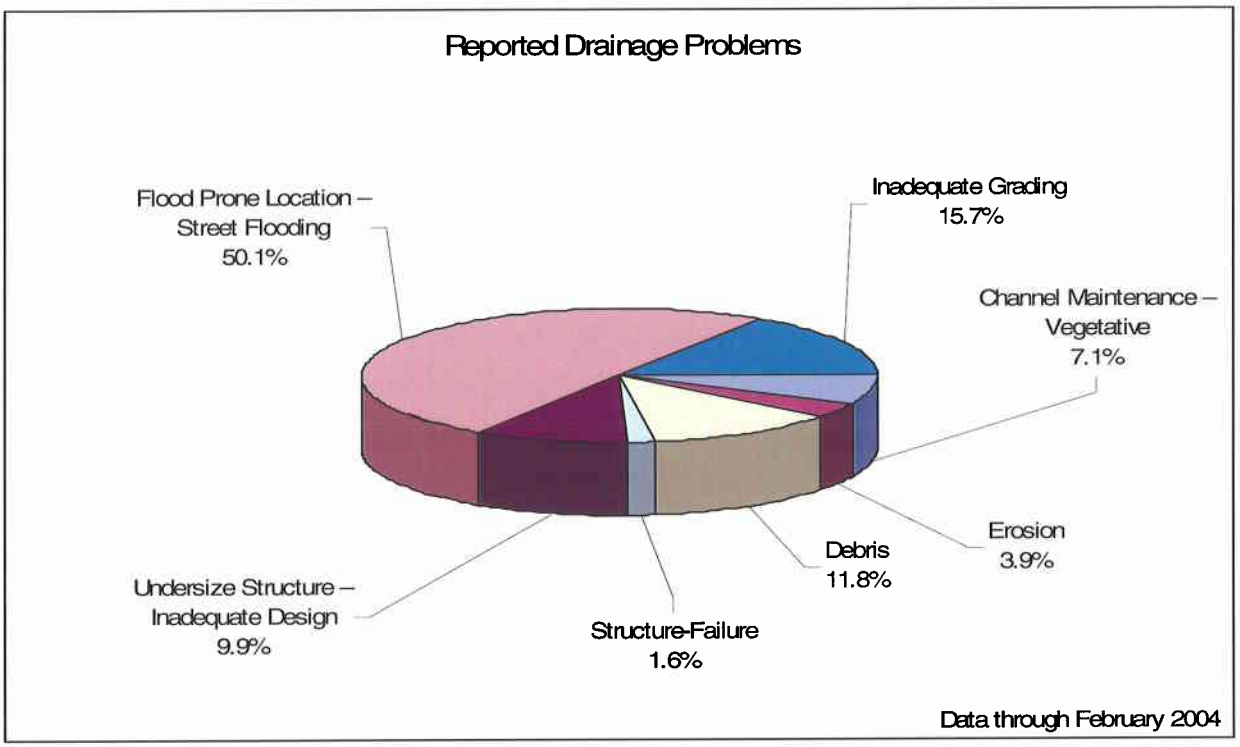

Figure 4.1: Reported Drainage Problem Categories

4.5 WATERSHEDS

The geographical distribution of reported drainage problems was evaluated on a watershed basis through use of a Geographic Information System (GIS). GIS mapping tools were used to overlay reported drainage problems on a map of the City (**Appendix B**). The City of Killeen was then divided into the sixteen major watersheds taken from the draft Halff FIS Re-study dated January 2003 and shown on **Exhibit B-1, Appendix B**. This exhibit indicates the wide-spread nature of drainage problems as well as localized problem areas.

4.6 WATERSHED STATISTICS

Reported drainage problems were mapped within each watershed, and the percentage of reported problems within each watershed were calculated. **Table 4.2** lists the sixteen watersheds, total number of events reported, and percentage of total events.

Table 4.2: Reported Drainage Problem, by Watershed

Watershed Number	Watershed Name	Number of Problems	Percent of Total
1	Long Branch	63	11.11
2	Caprice Ditch	20	3.53
4	Stewart Ditch	39	6.88
6	Liberty Ditch	7	1.23
7	Valley Ditch	20	3.53
9	Industrial Ditch	9	1.59
10	Atkinson Ditch	15	2.65
11	Hallmark Ditch	8	1.41
12	Bermuda Ditch	45	7.94
13	South Nolan Creek, South of 190	32	5.64
14	South Nolan Creek, North of 190	100	17.64
16	Little Nolan Creek, Tributary 1	90	15.87
17	Little Nolan Creek, North of 190	26	4.59
18	Stillwood Ditch	10	1.76
19	Little Nolan Creek, South of 190	29	5.11
20	Trimmier Creek	54	9.52

Table 4.2 indicates that the South Nolan Creek Watershed, north of U.S. Highway 190, (watershed number 14) exhibits the most drainage problems, closely followed by Little Nolan Creek, Tributary 1 Watershed (watershed number 16), and the Long Branch Watershed (watershed number 1). Combined, these three watersheds account for 44.52 percent of reported drainage problems. The prioritization of response activities within these watersheds must account for the total number of reported drainage problems, size of the watershed, and type of drainage problem. Administrative solutions could be used for developing watersheds that have had no significant drainage problems reported and have lower priority ranking.

Appendix A.3

Regulatory Influences
(Section 5 of 2005 DMP)

5.0 REGULATORY INFLUENCES

5.1 TEXAS WATER CODE

Section 11.086(a) of the Texas Water Code prohibits a person from diverting or impounding the natural flow of "surface water" in a manner that damages the property of another from the overflow of water diverted or impounded. On its face, this section of the Texas Water Code would appear to be a prohibition of any sort of drainage-related action that might cause harm to another.

However, over the years, the courts have held that surface water means diffused surface water. As soon as surface water reaches some sort of channel or defined course, it is no longer diffused surface water and the provisions of Section 11.086(a) no longer apply. In fact, courts have often held that downstream property owners have a certain obligation to accept upstream water in existing watercourses, even if the upstream flow has been changed somewhat as a result of an action of an upstream landowner.

Thus, Texas Water Law and subsequent common law court interpretations provide little guidance for municipalities related to many drainage issues involving upstream and downstream landowners. The failings of Section 11.086 in defining landowner rights related to drainage are so great that a recent Texas appeals court noted "a landowner might divert the entire Brazos River across his neighbor's property without subjecting himself to liability under Section 11.086 of the Texas Water Code."

Texas Courts have slowly provided more definition related to the rights of landowners and cities related to drainage. One case that bears watching is "City of Keller v. Wilson". In this case, a downstream landowner (Wilson) sued the City of Keller on an inverse condemnation theory related to the City's approval of drainage plans for an upstream developer. Wilson argued that perceived future damages resulting from the City's approval of the upstream developer's plans resulted in a taking of Wilson's property. The lower courts ruled in Wilson's favor, and the case is currently awaiting a hearing with the Supreme Court of Texas.

5.2 NATIONAL FLOOD INSURANCE PROGRAM

Established by the National Flood Insurance Act of 1968, the National Flood Insurance Program (NFIP) is an insurance program with some regulatory elements. The program was developed by the federal government to ensure that the nation's citizens could purchase affordable flood insurance for their property. Insurance is obtained from private insurance companies, but the federal government underwrites the program.

To reduce the federal government's exposure to flood loss costs, a national flood mapping system was initiated and a regulatory program was designed around the flood mapping system. Since the NFIP is a voluntary program, state and local governments have the ability to opt into or out of the program. If they elect to participate in the program, citizens within the local government's boundaries have the ability to purchase flood insurance at federally controlled

rates provided by private insurers. In return for opting into the program, participants agree to implement a local regulatory program designed to reduce flood losses.

If a community elects not to participate in the NFIP, citizens within the local boundaries will not be able to purchase flood insurance at federally controlled rates. Flood insurance might, in theory, be available from private insurers, although in practice, it usually is not available or is available only at market rates.

When communities elect to participate in the NFIP, the Federal Emergency Management Agency (FEMA) agrees to provide flood mapping (flood insurance rate maps otherwise known as FIRMs) for the community (although flood mapping studies may not be performed for several years). Communities, in turn, agree to adopt an ordinance regulating floodplain development and to establish minimum standards for structures to be constructed in and around the floodplain. The minimum ordinance standards usually establish a local permit program requiring floodplain development permits for proposed fill in the floodplain. Minimum finished floor elevations must be established at least 1 foot above the 100-year floodplain water surface elevation. FEMA has the ability to drop communities from the flood insurance program for continued lack of compliance with the regulatory aspects of the program.

Flood mapping to support the program is normally based on a set of computer hydrologic and hydraulic (H&H) models. Depending on the work proposed around or in the floodplain, it may be necessary for floodplain development permit applicants to revise the computer H&H models to reflect the proposal.

As the program is established, local communities act as the gatekeeper for letters of map revision (LOMRs), conditional letters of map revision (CLOMRs), and letters of map amendment (LOMAs), which are methods used by FEMA to adjust flood maps based on floodplain development permit submittals. The permit review, approval, and map revision gatekeeper function provided by local communities is usually tasked to the community floodplain administrator. In Killeen, the duties of floodplain administrator reside with the Building Official.

FEMA audits local community programs on a periodic basis through Community Assistance Visits (commonly called CAVs). A CAV was performed for the City in September 2003. Items noted by FEMA during the CAV included two potentially significant issues:

- Property owners appear to be underinsured (i.e., not enough structures appear to be insured in proportion to the potential flood risk).
- The City's flood mapping studies and FIRMs are outdated.

Both of these items are largely out of the City's control. For example, the decision to purchase flood insurance by a property owner is not controlled by the City. If the City's residents are underinsured, it is possibly due to a rapid property turnover rate. Nevertheless, the City will want to increase public information efforts associated with the need for flood insurance as part of its overall storm water management program public education efforts. Although the number of residences located within the mapped 100-year floodplain number less than 100, it should be

noted that, nationally, at least one-third of flood damage occurs in areas outside of mapped 100-year floodplains.

FEMA began remapping much of the city (primarily along the main stem of Nolan Creek) in early 2002. However, map production was delayed by resource conflicts at FEMA. FEMA is now conducting a Map Modernization Project for Bell County to produce digital floodplain maps, which will include the 2002 study data. However, FEMA is not conducting any new studies within Killeen to enhance the level of detail for the floodplain mapping. The City of Killeen contracted with Carter & Burgess to prepare hydrologic and hydraulic analysis for approximately 25 miles of floodplain to be provided to FEMA for inclusion in the FEMA Map Modernization Project.

The NFIP policy claims data and the location of floodplain boundaries within the City are included in **Appendix C**.

5.3 TEXAS POLLUTANT DISCHARGE ELIMINATION SYSTEM PROGRAM

National efforts to improve the quality of surface water bodies started in 1977 with the passage of the Clean Water Act (CWA). The main emphasis of this legislation was to establish a system to control pollution from point sources, with the goal of reducing pollutants so the nation's lakes and streams are both fishable and swimmable. To achieve this goal, the CWA established the National Pollutant Discharge Elimination System (NPDES). The NPDES requires that anyone discharging a pollutant from a municipal wastewater or industrial point source must obtain an NPDES permit, which specifies effluent limits, monitoring requirements, and enforcement mechanisms.

Over the past two decades, the CWA has evolved and now contains regulations to address pollution from storm water discharges. Phase I of the NPDES storm water regulations initiated with the passage of the Water Quality Act amendments of 1987, which required medium and large municipalities with populations to classify their storm water runoff and develop plans to reduce the pollutants in their runoff. Most Phase I cities are now well into their initial five-year permit terms.

The draft Phase II NPDES regulations were published on January 9, 1998 and the final Phase II regulations were published on December 8, 1999. Phase II extended the NPDES program to include most cities under 100,000 population and also lowered the Phase I construction storm water discharge permit threshold from five acres to one acre. Phase II also removed certain industrial storm water discharge permit exemptions that previously applied to smaller cities. Based on a survey of successful Phase I municipal programs, the EPA recognized that successful municipal storm water quality programs included six minimum control measure program elements:

- Educate the public on storm water impacts
- Involve the public in the development and operation of the program
- Establish procedures to detect and eliminate storm water pollutant discharges

- Control storm water runoff from construction sites
- Require permanent controls for post-construction storm water runoff
- Include good housekeeping practices for municipal operations

Phase II cities must develop a storm water management program addressing the six minimum control measures. A Notice of Intent (NOI) document must also be submitted to the permitting authority indicating the commitment of the Phase II city to comply with a general permit to be developed by the permitting authority.

The state of Texas is delegated by the EPA to manage the NPDES program in Texas (hence the Texas Pollutant Discharge Elimination System or TPDES). The Texas Commission on Environmental Quality (TCEQ) is the NPDES permitting authority for the state of Texas.

In 2002, TCEQ published a draft general permit for Phase II municipal separate storm sewer systems (MS4s) that would apply to cities such as Killeen. The permit was intended to take effect no later than March 10, 2003, which was the regulatory deadline for Phase II cities to have obtained their MS4 permit. However, TCEQ conflicts and an ongoing federal lawsuit regarding the provisions of the Phase II storm water program have delayed the TCEQ permit release.

A revised draft general permit for Phase II MS4s was released August 16th, 2005. It is open for another round of public comment until September 29th, 2005. Initial opinion is that TCEQ will have the permit finalized to become effective January 1, 2006.

On the surface, the Phase II program appears to be a water quality program with little impact on water quantity issues. However, Phase II requirements are actually far reaching and could positively impact the City's drainage program in several ways, including:

- Educational efforts could reduce illegal dumping and floatables into the city's storm water system, reducing the tendency for drainage features to clog.
- City enforcement efforts for the illicit discharge program could also reduce illegal dumping and floatables into the storm water system, reducing the tendency for drainage features to clog.
- Educational and enforcement efforts for the construction runoff program could reduce floatables and sediment to the City's drainage features, reducing the tendency for drainage features to clog.
- Runoff mitigation efforts associated with the post-construction control program could reduce flow in the City's drainage network and reduce channel erosion
- Increased City maintenance resources required as a result of the program could be used for water quantity maintenance as well as water quality maintenance.

The Phase II program encourages cities to look at integrated storm water management solutions. While traditional drainage design focused on removal of water from a city as quickly

as possible, Phase II encourages comprehensive programs for drainage design that address both the water quality and water quantity components.

The City has been very proactive in addressing Phase II requirements and is poised for compliance with the regulations as soon as the TCEQ general permit is released. Continued drainage system maintenance is a key Phase II requirement that must complement the City's ongoing drainage maintenance program.

5.4 USACE SECTION 404 PERMIT

The CWA Section 404 permit program regulates the placement of dredged or fill materials into the nation's waterways. The program is administered by the U.S. Army Corps of Engineers under agreement with the U.S. Environmental Protection Agency. The EPA maintains oversight responsibility for the program similar to the oversight responsibility that EPA maintains over state storm water programs.

The Section 404 program has its roots in a similar federal program that sought to ensure the nation's navigable waterways would not be blocked by the dumping of fill material into those waterways. As such, the program impacted only discharges of fill into the nation's largest waterways. Over the years, the program has expanded greatly in scope. Today, the program regulates even the smallest discharges (above very low threshold levels) into waters of the United States and adjacent wetlands. The waters of the United States definition is now very broad as well. Virtually any stream or natural drainage way in the City of Killeen potentially falls under the existing Section 404 program. While the program formerly focused on the protection of navigation interests, the existing program focuses on maintaining all the functions and values provided by natural stream corridors. As the program is now defined, the emphasis is on the protection of habitat for both the flora and fauna that commonly use or reside in the nation's stream corridors.

The current goals of the Section 404 permit program are consistent with the goals of this drainage master plan because evolving drainage practice focuses on usage of existing natural corridors rather than wholesale modification as practiced in the past. From a practical standpoint, virtually any fill or excavation activity within drainage ways (even man-made trapezoidal channels that were formerly natural drainage ways) requires a Section 404 permit.

Permits range from simple Nationwide Permits (somewhat similar to a NPDES general permit) to very complex Individual Permits. In many instances, the Corps seeks comments from related federal and state resource agencies on permit applications. For Individual Permits, the Corps will also seek public comment. For very complex projects, the Corps can require development of an Environmental Assessment or an Environmental Impact Statement.

To minimize impacts to the nation's waterways, the program is based on the concepts (in priority order) of avoidance of impacts, minimization of impacts, and mitigation of impacts. In other words, the Corps first requires that projects be designed to avoid or minimize impacts to the nation's waterways. If impacts are unavoidable, projects must be designed with mitigation to replace the stream or wetland functions impacted. Mitigation is usually required at ratios well above 1:1. For example, if a project impacts one acre of bottomland hardwoods, the Corps

might require the applicant to construct a mitigation area with three acres of bottomland hardwoods as replacement for the area impacted.

Table 5.1 lists some examples of how the Section 404 permit program impacts typical urban drainage projects.

Table 5.1 Typical Project Impacts of Section 404 Permit Requirements

Type of Project	Type of Permit Likely Required	Type of Mitigation Required	Favored Corps Solution
Roadway Drainage Culvert	Nationwide Permit	Possibly None	Bridge or ConSpan Crossing, Road Rerouting
Small Closed Storm Drainage System in Minor Drainage Way	Nationwide Permit	Possibly None	Reroute Road, Do Not Enclose Drainage way, Use Open System
Large Closed Storm Drain System in Urban Creek	Individual Permit	Replacement of Stream Functions at Ratios Greater than 1:1	Reroute Road, Do Not Enclose Drainage way, Use Open System
Open Grass-Lined Trapezoidal Channel	Nationwide or Individual Permit	Replacement of Stream Functions at Ratios Greater Than 1:1	Leave Existing Creek in Natural State
Open Concrete Lined Trapezoidal Channel	May Not Be Permittable – If Permittable, Individual Permit Likely	Replacement of Stream Functions At Very High Ratios	Leave Existing Creek In Natural State

In recognition of the Section 404 program requirements, the City requires a note on all plat submittals indicating that the development applicant recognizes the potential need for Section 404 permitting and agrees to obtain such permitting, if required.

In Texas, the Corps has focused most of its Section 404 enforcement efforts in the Dallas-Fort Worth Metroplex. As a result, the rules are relatively well understood in North Texas. However, in many parts of the state, the Section 404 requirements are virtually unknown or misunderstood.

5.5 NATIONAL DAM SAFETY PROGRAM

Congress established the National Dam Safety Program in 1978. Similar to other regulatory programs, this program has been passed down to the states to implement.

In Texas, the TCEQ implements the program. The program establishes minimum requirements for dam design, including embankment and spillway design requirements. In Texas, water impoundments greater than 6 feet in height are classified as dams.

The requirements of this program could take on greater importance as the City of Killeen moves forward with its Drainage Master Plan and Phase II Storm Water Management Plan because impoundments with embankments greater than six feet in height could form an important component of the City's drainage program. The City will need to develop specific design and maintenance requirements to ensure the ongoing safety and proper operation of such dams.

Permanent surface water impoundments could also be subject to TCEQ water appropriations permitting. Proposed ponds or existing stock tanks that are undergoing a land-use change would require water appropriations permits from TCEQ. New ponds or existing stock tanks that lose their exempt status are required to submit and receive a permit to impound state water. The City must ensure these permit requirements are being addressed during plat review.

5.6 RELATED REGULATORY PROGRAMS

In addition to the programs described in this section, influences from other agencies could impact the City's Drainage Master Plan efforts, including the following:

- Texas Department of Transportation Requirements
- Department of the Army Requirements
- State or Federal Agency NEPA Requirements
- Adjacent Local Government Requirements

Appendix A.4

Storm Water Management Plan
(Section 7 of 2005 DMP)

7.0 STORM WATER MANAGEMENT PLAN

7.1 PURPOSE OF PLAN

The objective of the Phase II Storm Water Management Plan (SWMP) is to develop a program with which the City of Killeen can reduce the discharge of pollutants to the Maximum Extent Practicable (MEP). This plan was developed with the input and direction of a stakeholders group to structure a proposed program for Killeen that meets state and federal program requirements and takes credit for current activities, addresses issues that will provide the greatest return on investment and is economically feasible.

The Texas Commission on Environmental Quality (TCEQ) has issued a digital general permit (Proposed General Permit No. TXR040000) for regulated small Municipal Separate Storm Sewer Systems (MS4s) covering eligible storm water and certain types of non-storm water discharges to surface water in the state. The proposed general permit provides requirements for operators of small MS4s for the development, implementation, and maintenance of a storm water management program.

7.2 PLAN DEVELOPMENT

Activities that were performed to support the Storm Water Management Plan development for the City of Killeen include:

- Review of existing storm water program information provided by the City
- Legal review of the City's storm water related ordinances
- Review of the City's existing storm water mapping information
- Detailed review of available water quality data in the Killeen area
- Preparation of a technical report summarizing the above information
- Three meetings of the Storm Water Stakeholders Group
- Business Stakeholders Group meeting
- Public Input Meeting
- Facilitatation of meetings with City departments
- Meetings with the City's GIS Coordinator
- Review of City facilities

The Storm Water Stakeholders Group assisted the City of Killeen in the development of their SWMP. The stakeholders group consisted of 23 citizens who represent a broad cross section of the City's constituency. The stakeholders included representatives from Texas Department of Transportation, Beautify Killeen, Fort Hood, City of Harker Heights, Texas State Soil and

Water Conservation Board, Bell County Public Health Department, as well as several homeowners, restaurant owners and developers.

Three meetings were conducted at the City of Killeen community meeting room at 207 W. Avenue D. The meetings typically began with a brief PowerPoint presentation, followed by a review of the BMP summary notebook for each minimum control measure and a discussion of the applicability of each BMP to Killeen. Each meeting concluded with the stakeholders voting on their "top five" BMPs for each minimum control measure. The proposed BMPs discussed in the following sections were selected based on input from the stakeholder group. Stakeholder meeting minutes are included in **Appendix J**.

7.3 PROPOSED MINIMUM CONTROL MEASURES

The draft Phase II TPDES regulations were published on January 9, 1998, and the final Phase II regulations were published on December 8, 1999. Based on a survey of successful Phase I municipal programs, the EPA recognized that successful storm water quality programs have several things in common, including that they:

- Educate the public on storm water impacts
- Involve the public in the development and operation of the program
- Review City facilities
- Control storm water runoff from construction sites
- Require permanent controls for post-construction storm water runoff
- Include good housekeeping practices for municipal operations

The EPA refers to these items as "Minimum Control Measures," and the Phase II regulations require the City of Killeen to "develop, implement, and enforce a storm water program to reduce the discharge of pollutants to the Maximum Extent Practicable, protect water quality, and satisfy the appropriate water quality requirements of the Clean Water Act."

7.3.1 PUBLIC EDUCATION AND OUTREACH

An effective public education program can significantly reduce other program costs, such as inspection and enforcement costs for the illicit discharge program. Informed citizens and business owners will usually take steps to reduce potential pollution from their own activities. The following list of Best Management Practices (BMPs) has been developed to modify the method and message on a regular basis in order to keep the program fresh and effective.

- Utility Bill Messages
- Storm Water Brochures
- Storm Water Web Site

- Public Service Announcements
- School Book Covers
- Classroom Education

7.3.2 PUBLIC PARTICIPATION AND INVOLVEMENT

In order for any regulatory program to be successful, especially a program dealing with storm water runoff where program benefits may not be readily apparent, public "buy in" to the regulatory process must be obtained. The following BMPs have been developed to easily allow the public to become involved in this storm water program.

- Storm Drain Stenciling
- Stream Cleanup Projects
- Storm Water Hotline

7.3.3 ILLICIT DISCHARGE DETECTION AND ELIMINATION

This program element is designed to ensure the elimination of illegal connections and discharges to the City of Killeen's storm water system. The regulatory language for the program element is very prescriptive and leaves little latitude for regulatory interpretation. However, the City is already performing some of the requirements of this program. The following list of BMPs includes current and new activities that meet regulatory requirements in the elimination of illicit discharges.

- Storm Drain System Mapping
- Illicit Discharge Ordinance
- Dry Weather Screening
- Illicit Discharge Investigations
- Sanitary Sewer Overflow Reduction
- Household Hazardous Material Disposal Options
- Reduction of Illegal Dumping
- Eliminate Failing Septic Systems

7.3.4 CONSTRUCTION SITE STORM WATER RUNOFF CONTROL

To date, control of construction site runoff has been the most publicly visible element of the storm water program. During a short period of time, construction sites can contribute more sediment to streams than can be deposited naturally during several decades. Therefore, this program may generate more enforcement activity than all other storm

water program elements combined. The following BMPs promote and monitor compliance with this program element.

- Construction General Permit Training
- Plan Review Procedures
- Construction Inspection
- Development Stakeholder Group
- Erosion Control Ordinance

7.3.5 POST-CONSTRUCTION STORM WATER MANAGEMENT IN AREAS OF NEW DEVELOPMENT AND REDEVELOPMENT

Numerous studies have documented that storm water runoff from developed sites contributes significant pollutant loads to receiving waters. To address this issue and comply with the regulatory requirements for this program element, the following BMPs have been recommended.

- Development/Redevelopment Stakeholder Group
- Post-Construction Ordinance
- Long-Term Operation and Maintenance of BMPs
- List of Water Quality CIP Projects

7.3.6 POLLUTION PREVENTION/GOOD HOUSEKEEPING FOR MUNICIPAL OPERATIONS

It is difficult to convince citizens of the need for storm water pollution prevention if the municipality is not "practicing what it preaches." Therefore, an effective municipal storm water program must be founded on an effective pollution prevention program for municipal facilities and field operations. Below is a list of currently performed and new BMPs, which are necessary to meet regulatory requirements for this program element.

- Storm Water Pollution Prevention Training
- Vehicle Maintenance
- Vehicle Washing
- Vehicle Fueling
- Landscape and Lawn Care
- Roadway Cleaning
- Storm Drain System Cleaning
- Hazardous Materials Storage and Disposal
- Used Oil Collection & Recycling

7.4 PLAN IMPLEMENTATION

While the City of Killeen is currently performing some of the previously listed BMPs under existing programs, the Storm Water Management Plan will be implemented after the final General Permit No. TXR040000 has been issued. TCEQ has issued a revised draft permit and is accepting public comment. Initial opinion is that the permit will be finalized January 1, 2006. The specific implementation schedule and measurable goals are summarized in the following table. The City of Killeen Plan Summary is included in **Table 7.1**.

Table 7.1 Proposed Storm Water Best Management Practices

STORM WATER MANAGEMENT PLAN	PLAN SUMMARY
The table below lists the measurable goals developed for each BMP and the year in which they are to be implemented.	

BMP	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Utility Bill Inserts	1 catalog 2 inserts mailed	2 inserts mailed	2 inserts mailed	2 inserts mailed	2 inserts mailed
Storm Water Brochures	1 list of topics 1 catalog 1 summary brochure	1 list of locations 1 new topical brochure	1 new topical brochure	1 new topical brochure	1 new topical brochure 1 catalog
Storm Water Web Site	Web site online by end of Year 1	2 new pages	1 new page	1 new page	1 new page
Public Service Announcements	Number of available slots Catalog - cable access PSAs	24 cable broadcasts Catalog - radio PSAs	24 cable broadcasts	24 cable broadcasts 4 radio broadcasts	24 cable broadcasts 4 radio broadcasts
School Book Covers	1 catalog	1 mock-up book cover	5,000 covers provided	5,000 covers provided 1 winning design	5,000 covers provided
Classroom Education	None	Catalog of curricula Meeting with ISD Set of modifications	List of grades List of teachers Packets for each teacher	1 session for each teacher	1 session for each teacher
Storm Drain Stenciling	1 catalog 1 mock up packet selected design	1 summary flyer GIS inlet map At least 1 stenciling event	At least 2 stenciling events	At least 3 stenciling events	At least 3 stenciling events
Stream Cleanup Projects	None	List of locations 1 mock up packet	1 summary flyer at least 1 clean up event	1 summary flyer at least 1 clean up event	1 summary flyer at least 1 clean up event
Storm Water Hotline	1 hotline established List of investigations	List of investigations	List of investigations	List of investigations	List of investigations
Storm Drain System Mapping	Little Nolan Creek watershed mapped	South Nolan Creek watershed mapped	Long Branch watershed mapped	Hay Branch watershed mapped	Reese and Trimmier Creek watershed mapped
Illicit Discharge Ordinance	1 draft ordinance	1 adopted ordinance	Written enforcement procedures	None	None
Dry Weather Screening	List of parameters Purchase order	South Nolan and Little Nolan watershed screening map	Long Branch watershed screening map	Hay Branch watershed screening map	Reese and Trimmier Creek watershed screening maps

Table 7.1 Proposed Storm Water Best Management Practices **(continued)**

STORM WATER MANAGEMENT PLAN | ***PLAN SUMMARY***

The table below lists the measurable goals developed for each BMP and the year in which they are to be implemented.

BMP	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Illicit Discharge Investigations	List of investigation types and locations	List of investigation types and locations	List of investigation types and locations	List of investigation types and locations	List of investigation types and locations
Eliminate Sanitary Sewer Overflows	Clean 350,000 ft / year TV 12,000 ft / year	Clean 350,000 ft / year TV 12,000 ft / year	Clean 350,000 ft / year TV 12,000 ft / year	Clean 350,000 ft / year TV 12,000 ft / year	Clean 350,000 ft / year TV 12,000 ft / year
Household Chemical Disposal	Written tracking procedure List of requests	Flyer / brochure / web page List of requests	Flyer / brochure / web page List of requests	List of requests Evaluation report	List of requests
Reduce Illegal Dumping	GIS map of dump locations	GIS map of dump locations	GIS map of dump locations	GIS map of dump locations	GIS map of dump locations
Reduce Failing Septic Systems	Map of septic systems	Mock-up brochure	List of distribution locations Map of new sewer and conversions	List of distribution locations Map of new sewer and conversions	List of distribution locations Map of new sewer and conversions
Construction General Permit Training	Attendance sheet from 1 class	Attendance sheets from 2 classes	None	None	None
Plan Review Procedures	Compliance report	Compliance report	Compliance report	Compliance report	Compliance report
Construction Inspection	None	Adopted procedures	List of inspections	List of inspections	List of inspections
Development Stakeholder Group	Flyers Invitation list	Minutes of 2 meetings	Minutes of 2 meetings	None	None
Strengthen Erosion Control Ordinance	Draft ordinance	Written procedures	Adopted ordinance	None	None
Development Stakeholder Group	Flyers Invitation list	Minutes of 2 meetings	Minutes of 2 meetings	None	None
Post-Construction Ordinance	None	Catalog of ordinances	None	Adopted ordinance	Design manual
Long-Term Operation and Maintenance of BMPs	None	List of BMPs	None	BMP GIS coverage	BMP GIS coverage
List of Water Quality CIP Projects	None	List of water quality CIP projects	None	BMP GIS coverage	None

Table 7.1 Proposed Storm Water Best Management Practices (continued)

STORM WATER MANAGEMENT PLAN	PLAN SUMMARY

The table below lists the measurable goals developed for each BMP and the year in which they are to be implemented.

BMP	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Storm Water Pollution Prevention Training	BMP/SOP manual 1 training per department	1 training per department	1 training per department	1 training per department	1 training per department
Vehicle Maintenance	Document measures	Document measures	Document measures	Document measures	Document measures
Vehicle Washing	Maintenance log	Maintenance log	Maintenance log	Maintenance log	Maintenance log
Vehicle Fueling	UST system report 1 speed bump	UST system report Verification of containment	UST system report Verification of containment	UST system report	UST system report
Landscape and Lawn Care	Licensed applicators	Licensed applicators	Licensed applicators	Licensed applicators	Licensed applicators
Roadway Cleaning	5,000 lane miles	5,000 lane miles	5,000 lane miles	5,000 lane miles	5,000 lane miles
Storm Drain System Cleaning	None	GIS inlet coverage	GIS inlet coverage	GIS inlet coverage	GIS inlet coverage
Hazardous Materials Storage & Disposal	Additional storage units Written procedures	2 training sessions	2 training sessions	2 training sessions	2 training sessions
Used Oil Collection & Recycling	Document disposal	Document disposal	Document disposal	Document disposal	Document disposal

Appendix A.5

Nonpoint Source Pollution Assessment (Section 8 of 2005 DMP)

8.0 NON-POINT SOURCE POLLUTION ASSESSMENT

The nature and extent of non-point source (NPS) pollution associated with urban areas within the City of Killeen and its extraterritorial jurisdiction (ETJ) is being assessed through a surface water quality monitoring program. This program will include wet-weather and ambient monitoring of stream water quality parameters at 14 sites in the South Nolan Creek and Lampasas River watersheds. The water quality monitoring program was initiated in fiscal year (FY) 2004-2005 and included nine sites in the South Nolan Creek watershed. In FY 2005-2006, the monitoring will be expanded to include five additional sites in the Lampasas River watershed.

Funding for the water quality monitoring program was secured through federal grants administered by the United States Environmental Protection Agency (EPA). Two NPS Clean Water Act (CWA) Section 319(h) grants were approved by the EPA and the Texas Commission on Environmental Quality (TCEQ) for funding. The FY 2004-2005 NPS grant encompassed monitoring activities within the South Nolan Creek watershed. The FY 2005-2006 grant extends the monitoring activities to areas of the city that drain to the Lampasas River and Stillhouse Hollow Lake. Both grant projects will continue for three years from the date of the award. CWA Section 319(h) grants require a 40 percent local match for each project. EPA reimburses the grantee 60 percent of the total project cost. The City's 40 percent local match will be provided by a combination of "in-kind" services performed by city personnel and professional services contracts related to grant activities.

Depending on the findings and recommendations resulting from the initial studies, the City may decide to continue monitoring at selected sites to document trends or the effectiveness of storm water BMPs.

The purpose, scope and objectives of Killeen's surface water quality monitoring program is discussed in the following sections.

8.1 PURPOSE OF PROJECTS

The purpose of both NPS grant projects is to address water body impairments that have been documented by TCEQ and determine the extent to which the City of Killeen may be contributing to water quality problems.

8.1.1 CURRENT WATER QUALITY STATUS AND POTENTIAL TMDLS

Both South Nolan Creek, which drains the northern portion of the city, and the Lampasas River, which receives storm water runoff from the southern portion of the city, are listed on the State's 303(d) list for impairment of contact recreation use due to elevated bacteria concentrations. The source of the bacterial contamination is unknown. Based on the location of historical state monitoring sites, it is unknown whether the urban areas of Killeen are a major source of contamination. Killeen's surface water quality

monitoring program will enable the City to document the occurrence of pollutants and identify areas of the City that are major contributors.

The State's 303(d) list, so named because of provisions in Section 303(d) of the federal CWA, is published by TCEQ in even-numbered years and is subject to EPA approval. Water bodies that do not meet State water quality standards are listed on the 303(d) list and may be targeted by TCEQ for a comprehensive analysis called a Total Maximum Daily Load (TMDL) study. A TMDL study examines all the point sources (end-of-pipe discharges) and non-point sources (diffuse discharges) of a particular pollutant in a watershed. The TMDL then allocates the amount that can be discharged while maintaining the beneficial use of the water. The allocations of point sources are called waste load allocations (WLAs), and the allocations of non-point sources are called load allocations (LAs). The TMDL must also consider natural background sources that may be present and include a margin of safety for the assessment. The following equation represents the components of a TMDL:

$$TMDL = \sum LAs + \sum WLAs + Background + MOS$$

where:

TMDL = Total Maximum Daily Load (kg/day)
$\sum$ LAs = Sum of Load Allocations (Non-Point Sources) in a watershed
$\sum$ WLAs = Sum of Waste Load Allocations (Point Sources) in a watershed
Background = Background Load from natural sources in a watershed
MOS = Margin of Safety

Background pollutant loads originate from natural sources in the watershed that are not related to human activities. For bacteria, natural sources may include native wildlife populations. As a component of a TMDL, background loads cannot be readily controlled or reduced and are therefore static in the TMDL equation. To meet the TMDL that is allowable in the watershed, the LAs and WLAs are reduced from current levels. From a regulatory standpoint, the load reductions are imposed through effluent limits placed in new and renewed permits issued by TCEQ. This can affect future MS4 permits, as well as discharge permits for municipal wastewater treatment plants that discharge to impaired water bodies.

Once a water body becomes impaired, there are three options the TCEQ has for addressing the impairments. The first option is to conduct a TMDL study and develop a plan to implement it. If there are some questions about the validity of the water quality standards or the data used to assess the water quality, the TCEQ may opt to postpone the TMDL study while a review of the water quality standards or additional data collection is being performed. Further evaluation may be necessary to determine if the current standard is appropriate or to determine the cause of the impairment.

The State of Texas is under mandate by the EPA to develop quantitative numerical criteria for nutrients as part of its water quality standards. Currently, Texas uses narrative criteria to govern acceptable quantities of nutrients in water bodies. The ill-defined narrative criteria are somewhat subjective and are evaluated by comparisons to TCEQ adopted screening levels. Nutrients are deemed a concern when a prescribed

number of the samples exceed the screening level. The timeline set forth by TCEQ for nutrient criteria development focuses on reservoirs first with anticipated development by 2006. Nutrient criteria for rivers and streams are anticipated to be developed by 2010.

The TCEQ has determined that additional data is needed for South Nolan Creek and the Lampasas River before a TMDL study is scheduled. Because TMDLs may be imposed in either of these watersheds, it is critical that the City of Killeen characterize its contribution to water quality impairment. Because TMDL implementation within a watershed brings with it additional regulatory requirements that can be imposed on permitted dischargers, it is important that regulatory decisions be based on accurate data and sound science. It is also important that the data reflect contributions from Killeen, rather than a composite view of several urban areas based on a downstream sampling site.

In addition to the bacterial impairment, historically elevated levels of nutrients such as nitrogen and phosphorus are documented in samples collected from South Nolan Creek. Over 70 percent of the samples collected by TCEQ show elevated concentrations of nitrate plus nitrite nitrogen, orthophosphate phosphorus, and total phosphorus. These pollutants are currently listed as a concern and are not included on the 303(d) list. With efforts underway by the State to develop numeric nutrient criteria, these pollutants may be upgraded from a concern to an impairment in the future.

8.1.2 DESIGNATED USES AND WATER QUALITY STANDARDS

The City of Killeen's surface water monitoring program will address urban NPS pollutant contributions from urbanized areas in three classified segments: South Nolan Creek (Segment 1218), the Lampasas River (Segment 1217), and Stillhouse Hollow Lake (Segment 1216). South Nolan Creek receives storm water runoff from the northern and western portions of the city, and the Lampasas River and Stillhouse Hollow Lake receive storm water from the southern portion of the city.

Designated uses for water bodies receiving storm water runoff from the City of Killeen include aquatic life use, contact recreation use, general use, fish consumption use, and public water supply (**Table 8.1**). For each of the designated uses that a water body is determined to have, a set of specific State of Texas water quality criteria are imposed by TCEQ. Water quality criteria relevant to receiving water bodies are listed in **Table 8.2**.

Table 8.1 Designated Uses

Segment ID	Water Body Name	Designated Uses				
		Contact Recreation	Aquatic Life	Public Water Supply	General	Fish Consumption
1216	Stillhouse Hollow Lake	X	Exceptional	X	X	X
1217	Lampasas River Above Stillhouse Hollow Lake	X	High		X	X
1218	Nolan Creek/ South Nolan Creek	X	High		X	X

Table 8.2 Water Quality Criteria

Segment ID	Water Body Name	Chloride[1] mg/l	Sulfate[1] mg/l	Dissolved Solids[1] mg/l	Dissolved Oxygen[2] Minimum mg/l	Min pH[3]	Max pH[3]	E.Coli[4]	Fecal Coliform[4]	Temperature[5] Maximum F
1216	Stillhouse Hollow Lake	100	75	500	6	6.5	9	126	200	93
1217	Lampasas River Above Stillhouse Hollow Lake	500	100	1200	5	6.5	9	126	200	91
1218	Nolan Creek/ South Nolan Creek	100	75	500	5	6.5	9	126	200	93

[1] chloride, sulfate, and dissolved solids criteria are expressed as a maximum annual average
[2] dissolved oxygen criteria relate to the minimum 24-hour mean
[3] pH criteria are set for the minimum and maximum values expressed in standard units
[4] E. coli and Fecal Coliform expressed as the geometric mean in CFU/100mL
[5] temperature criteria are the maximum values allowed at any site within the segment

As previously discussed, the TCEQ uses screening levels in the absence of nutrient criteria to identify concerns associated with the narrative criteria. The screening levels for nutrients and chlorophyll-a are the same statewide but vary depending on the type of water body. The TCEQ has established screening levels for freshwater streams, reservoirs, tidal streams, and estuaries. The screening levels that are applicable to water body types that will be monitored for NPS pollution are listed in **Table 8.3**.

Table 8.3 Narrative Criteria (TCEQ Screening Levels) for Nutrients and Chlorophyll-a

Water Quality Parameter	Freshwater Streams	Reservoirs
Ammonia Nitrogen (mg/L)	0.17	0.106
Nitrate plus Nitrite Nitrogen (mg/L)	2.76	0.32
Orthophosphate Phosphorus (mg/L)	0.5	0.05
Total Phosphorus (mg/L)	0.8	0.18
Chlorophyll-a (mg/L)	11.6	21.4

8.2 PROJECT SCOPE AND OBJECTIVE

Surface water quality monitoring will be coupled with implementation of the City's Storm Water Management Program to address problem areas that are identified through monitoring. Killeen's SWMP will include several BMPs that will reduce the quantity of bacteria contamination. In addition to E. coli bacteria, the City will monitor typical NPS pollutants associated with urban runoff, including sediment, nutrients, metals, oil/grease, biochemical oxygen demand, and physicochemical parameters such as dissolved oxygen, conductivity, pH, and temperature. The major objectives identified for the NPS assessment projects include:

OBJECTIVE 1: PROJECT ADMINISTRATION

Goal: To effectively administer the functions necessary to coordinate and monitor all work performed for the 319 grant projects, including technical and financial supervision, preparation of status reports, and maintenance of project files and data.

Progress reports will document all activities performed by any subcontractor(s) and will be submitted no later than thirty (30) days after the close of the quarter.

OBJECTIVE 2: WATER QUALITY MONITORING & DATA COLLECTION

Goal: To quantify non-point source pollutants within the South Nolan Creek and Lampasas River watersheds and, through analysis of the data, identify priority areas within the City of Killeen for BMP implementation related to bacterial sources.

This process requires an inventory of the potential sources within the watershed, site identification, installation of automatic samplers for wet-weather monitoring, and initiation of a routine monitoring program. Monitoring efforts and data collection will be conducted by the City of Killeen with assistance from the Texas Institute for Applied Environmental Research (TIAER).

OBJECTIVE 3: WATERSHED CHARACTERIZATION

Goal: To obtain information on potential sources of bacteria in the watershed and to characterize the nature of bacterial sources above each sampling site.

The City will characterize the location of potential pollutant sources in the watershed, particularly those sources related to bacteria. A GIS-based coverage will be developed of On-Site Sewage Facilities (OSSFs) in the watershed. The watershed characteristics will be used in conjunction with monitoring results to target priority areas in the watershed for BMP implementation.

OBJECTIVE 4: COORDINATION AND STAKEHOLDER INVOLVEMENT

Goal: To coordinate with other monitoring groups and share information with local stakeholders regarding water quality monitoring programs in the Lampasas River Watershed.

A representative from Killeen will participate in regularly scheduled meetings of the Lake Stillhouse Hollow Clean Water Steering Committee and share information regarding monitoring

program status and results. A City representative will also participate in coordinated monitoring meetings held at the Brazos River Authority office in Waco, Texas.

OBJECTIVE 5: FINAL REPORT

Goal: To provide TCEQ and EPA with a comprehensive report on the activities conducted by the City of Killeen during the course of this project.

To accomplish this goal, the City will consolidate water quality and watershed characteristics into a spreadsheet or similar database suitable for tabulating, sorting, and analyzing the data. Statistical techniques will be used to summarize the data and examine relationships and trends. Based on the results, the City will identify priority areas for BMP implementation as part of its Phase II MS4 SWMP.

8.3 PROJECT IMPLEMENTATION

8.3.1 MONITORING IN THE SOUTH NOLAN CREEK WATERSHED

The surface water monitoring program in the South Nolan Creek Watershed will include routine and wet-weather monitoring at six sites on South Nolan Creek and three tributaries flowing into South Nolan Creek (**Exhibit 8.1**) for bacteria, nutrients, organics, sediment, oil and grease, and metals as identified in **Table 8.4**. Sampling for E. coli bacteria will occur on a monthly basis at nine sites. Other water quality parameters will be monitored semi-annually at sites along the main stem of South Nolan Creek. A GIS coverage of OSSF locations within the city will be used in conjunction with water quality data to identify priority areas for OSSF inspections, sewer conversions, and targeted public education.

Table 8.4 Water Quality Constituents

NO_2+NO_3-N	Nitrite + Nitrate Nitrogen
NH_3-N	Ammonia Nitrogen
TKN	Total Kjeldahl Nitrogen
PO_4-P	Ortho-Phosphate Phosphorus
TP	Total Phosphorus
TSS	Total Suspended Solids
O & G	Oil & Grease
BOD5	Biochemical Oxygen Demand (5-day)
E. Coli	*Eschericia coli* bacteria
DO	Dissolved Oxygen
pH	pH
Cond	Specific Conductance
Temp	Water Temperature

8.3.2 MONITORING IN THE LAMPASAS RIVER WATERSHED

The monitoring program in the Lampasas River Watershed will include the same types of constituents as described above for the South Nolan Creek monitoring program. Monitoring will be conducted at five sites within the Lampasas River Watershed (**Exhibit 8.2**). Wet-weather monitoring with automated samplers will be implemented at three tributary sites (Sites LR1, LR2, and LR3), and routine monitoring will be conducted on a quarterly basis at two sites (Sites LR4 and LR5) on the Lampasas River. Two major tributaries were selected for monitoring storm water contributions from the City. These include Trimmier Creek, which drains the southeastern portion of the City and flows into Stillhouse Hollow Lake, and Reese Creek, which drains the southwestern portion of the City and conflows with the Lampasas River. Both the Trimmier Creek and Reese Creek watersheds contain residential areas that utilize on-site sewage facilities (OSSFs) and are representative of urban watershed contributions from the City of Killeen. Storm water sampling on Trimmier and Reese Creeks will allow the City to characterize pollutant event mean concentrations (EMCs) from urban storm water runoff that may impact the quality of water in the Lampasas River and Stillhouse Hollow Lake. Stream flow in Reese and Trimmier Creeks are intermittent in nature and will be sampled only during storm events.

In addition to storm water monitoring at three sites (Sites LR1, LR2, and LR3), the City will perform routine monitoring at two sites on the Lampasas River (Sites LR4 and LR5). These sites were chosen to isolate the contributions from the Reese Creek watershed using an upstream-downstream approach. Site 5, located upstream from the Reese Creek confluence, is not impacted by storm water runoff from the City of Killeen. Site 5 will be used to characterize stream concentrations from the upper watershed. Site 4 is located on the Lampasas River at SH 195, downstream from the Reese Creek confluence. Other than the Reese Creek watershed, the interceding drainage area between Sites 4 and 5 is minimal. The minor tributaries that confluence with the Lampasas River between Sites 4 and 5 drain undeveloped areas, with no significant sources of pollution identified. Comparison of stream concentrations observed at these two sites will quantify the impact of urban runoff from the Reese Creek watershed. A paired t-test or comparable non-parametric statistical test will be used to determine if significant differences exist between these two sites.

Routine monitoring will include monthly sampling for *E. coli*. All other parameters will be monitored on a quarterly basis. Quarterly sampling is proposed to ensure that a sufficient number of samples are collected to utilize parametric statistical tests when analyzing the data. Monthly sampling for *E. coli* bacteria will ensure consistency with monitoring programs in portions of the city that drain into South Nolan Creek.

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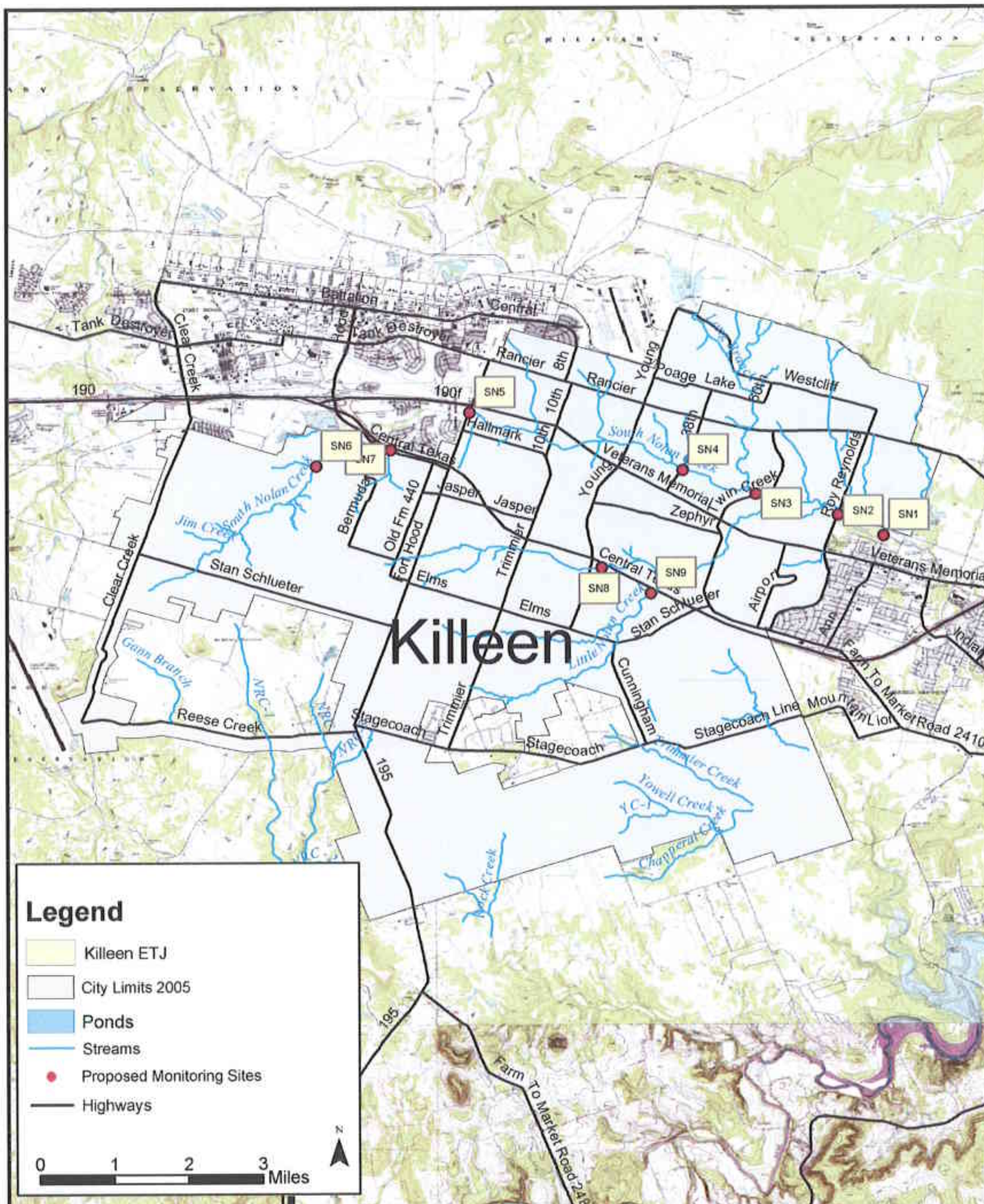
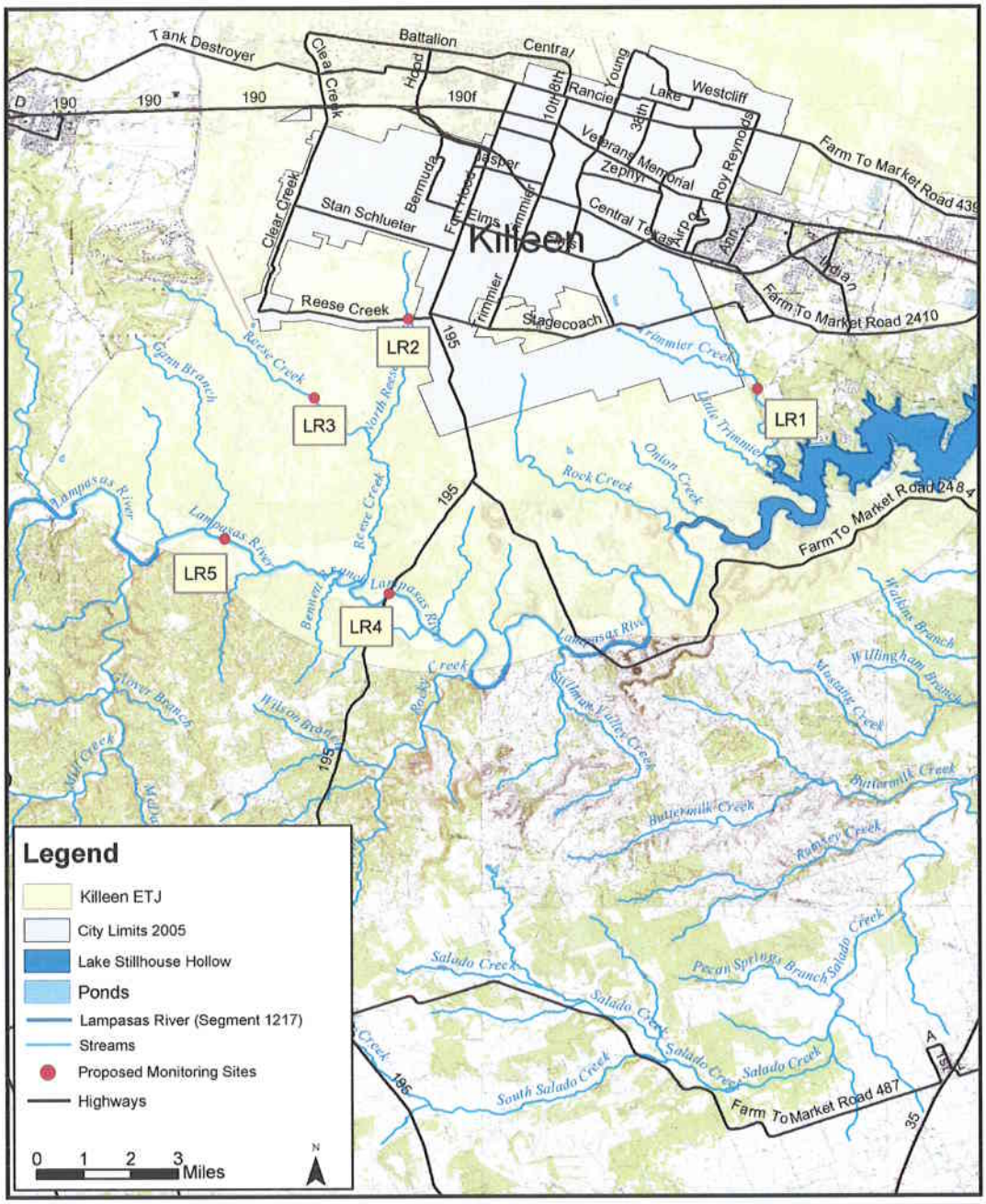


Carter::Burgess	FY 2004 EPA 319(h) Nonpoint Source Grant Project	South Nolan Creek Sampling Sites Sources: TNRIS, TCEQ, USGS and City of Killeen Basemap-USGS Quadrangle	Exhibit 8.1



Carter::Burgess	FY 2005 EPA 319(h) Nonpoint Source Grant Project	**Lampasas River Watershed Sampling Sites** Sources: TNRIS, TCEQ, USGS and City of Killeen Basemap-USGS Quadrangle	**Exhibit** **8.2**

Appendix A.6

Drainage Maintenance Plan
(Section 10 of 2005 DMP)

10.0 DRAINAGE MAINTENANCE PLAN

10.1 CONDITION ASSESSMENT

Before establishing a maintenance plan for the City of Killeen's drainage system, an initial assessment must be conducted to determine existing standards, initial maintenance needs, and potential risks. A protocol for field inspection of the stream corridors must be prepared so that a field crew can easily implement the protocol while walking the stream corridors. Once a protocol is developed, all open channel stream corridors in the city will be investigated. Field investigation will provide initial condition assessment and maintenance needs of each section. Upon completion of the field investigation, initial maintenance will be conducted to establish a baseline condition for all sections of the stream corridors.

A routine maintenance plan will be developed to maintain the stream corridors and periodically return them to baseline conditions. It will include a schedule of maintenance activities for each section and for resource needs. The maintenance plan will also coordinate with City maintenance staff regarding existing resources and maintenance techniques. It will also provide suggestions to reduce future maintenance requirements or provide City maintenance staff easier access for maintenance activities. Maintenance of the stream corridors will protect flood carrying capacity and could also reduce the possibility of man-made drainage ways becoming jurisdictional waters under the CWA. Maintenance of jurisdictional waters is more complicated and costly than non-jurisdictional waters; thus, the maintenance plan will address maintenance of jurisdictional waters.

10.2 EXISTING DRAINAGE INFRASTRUCTURE MANAGEMENT

Culverts, bridges, storm drains, channels, and stream corridors are part of the drainage infrastructure and require management similar to water, sanitary sewer, and transportation infrastructure. The City's GIS program will include all drainage infrastructure within the storm data layer. This information will provide a management tool to schedule maintenance, inspection, and, if necessary, replacement. Proper management of drainage infrastructure will reduce the need for minor and major CIPs.

10.3 PLANNED DRAINAGE INFRASTRUCTURE MANAGEMENT

As the City of Killeen develops and grows, the City's drainage infrastructure will grow. The City must review and approve all proposed drainage infrastructure to ensure it meets City requirements and minimize the need for fixing or replacing inadequate drainage structures. As drainage infrastructure is constructed and accepted by the City, the infrastructure must be added to the City GIS system and maintenance plan.

Appendix A.7

Administrative Solutions (Section 11 of 2005 DMP)

11.0 ADMINISTRATIVE SOLUTIONS

Physical improvements are not always the primary means to improve the drainage system and remove drainage stressors. Alternately, soft or administrative solutions can be implemented to reduce stressors and improve efficiency of the drainage system. These solutions can involve code and policy changes, or additional program resources.

11.1 ORDINANCE DEVELOPMENT

Potential administrative solutions related to city ordinances were identified in the City of Killeen Drainage Master Plan Scoping Study. Revisions to the City of Killeen Code of Ordinances and drainage criteria would elevate the level of flood protection, improve the function and the health of drainage infrastructure, and reduce chronic maintenance problems. Recommendations for revised or new city ordinances were outlined:

- Establishment of minimum finished floor elevations at 18-inches above the FEMA regulatory 100-year water surface elevation
- Use of ultimate development conditions to determine peak discharges and flood elevations
- Establishment of erosion and sediment control ordinance for all construction sites greater than one acre

Revisions to the Code of Ordinances and drainage criteria that establish a minimum finished floor elevation 18-inches above the 100-year water surface elevation would reduce flood claims, improve the community rating, and lower flood insurance rates for the community.

The City currently follows FEMA policy, which allows for the use of existing development conditions for the evaluation of peak discharge. For rapidly developing watersheds, this policy may not accurately represent development impacts on flood levels. The City of Killeen is experiencing rapid development in some areas, particularly in the headwaters of the watersheds. As the City's watersheds are developed, the 100-year water surface elevations could increase 1 to 3 feet downstream from recent and future development. Modifications to the Code and drainage criteria requiring the use of ultimate development discharges would provide an increased level of flood protection, thereby reducing future flooding problems and reducing the need for future CIPs related to flooding and drainage problems.

Establishment of an erosion and sediment control ordinance for all construction sites greater than one acre would reduce or eliminate problems caused by grading and development activities. Such an ordinance would be consistent with TCEQ storm water program requirements. The TCEQ storm water program also requires cities to develop a construction runoff control program. The City of Killeen could opt to implement general requirements as outlined by the TCEQ or could choose to adopt local erosion and sedimentation requirements tailored to the City's needs. Establishment of an erosion and sediment control ordinance would

reduce drainage infrastructure maintenance, support drainage infrastructure performance, improve water quality, protect habitat and water supply, and support compliance with TPDES storm water permit requirements.

11.2 DRAINAGE DESIGN CRITERIA REVISIONS

The current drainage design criteria were established November 4, 1992, for simplicity of design and review. However, standard civil engineering practices have evolved since 1992, and alternative methods that provide more detailed analysis are readily available. Computer modeling has become an industry standard for hydrologic and hydraulic analysis, which provides more detailed information during the design of drainage systems. The City of Killeen must incorporate revised criteria for hydraulic analysis to be consistent with standard industry practices.

Hydrologic analysis of small watersheds is still commonly performed using the Rational Method. However, industry standards have redefined the limits of "small" watersheds. FEMA currently limits the use of the Rational Method to watersheds under 200 acres; many municipalities in Texas have even smaller thresholds.

Hydraulic analysis of storm drains and small drainage systems is still commonly performed using Manning's equation. However, computer modeling that provides more detailed information is readily available to perform hydraulic analysis for these and open channel systems. Hydraulic modeling provides information on the system or channel reach, whereas the Manning's equation provides information at an isolated location. The complexities of drainage systems and channel reaches require information through the entire system to effectively evaluate hydraulic conditions. Hydraulic modeling also provides a valuable tool for future drainage infrastructure management.

Typical channel sections provided in the current drainage design criteria do not provide the City with a preferred channelization alternatives. Trapezoidal channels are efficient means to convey flood discharges; however, they do not address stream stability during low flow and many other factors that affect stream and channel sections. The concrete section is no longer industry standard, and adverse impacts are created with its use. Both trapezoidal earthen and concrete lined channel sections are difficult to permit under the Clean Water Act Section 404 Program. In accordance with evolving practices, channelization must be designed on a site-by-site basis to utilize beneficial items located within the existing channel reach and provide channel stability.

In recognition of the Section 404 program requirements, the City requires a note on all plat submittals indicating the development applicant recognizes the potential need for Section 404 permitting and agrees to obtain such permitting, if required. However, the City development review process does not have any means in place to ensure that plat applicants comply with Section 404 permit requirements. The City should consider amending its development review process to require that plat applicants submit documentation that they have complied with any applicable Section 404 permit requirements. There are several milestones in the development review process where such proof of Section 404 compliance could be required. Proof could be required before plat approval, before building permit issuance, before public infrastructure acceptance, or before issuance of other related permits such as the City Floodplain

Development permit in those development situations where such permits are required. However, the 404 permit process can be quite time consuming – many permits require up to 18 months to process – so an up front proof of compliance requirement could delay development cycles by several months.

As part of its ongoing Drainage Master Plan and Phase II storm water management program efforts, the City should also consider educational efforts to educate the public and development community about Section 404 requirements.

TCEQ water appropriations and dam safety programs also require permitting that should be addressed during the platting of a proposed development. The City should also require a note on all plat submittals indicating the development applicant recognizes the potential need for a TCEQ Water Appropriations Permit, including possible dam safety analysis. The City should amend its development review process to require proof that plat applicants have complied with any applicable TCEQ water appropriations permit requirements. Similar to the Section 404 permit process, the TCEQ approval process can also be time consuming and requirement of such proof of compliance can also delay development cycles. Some smaller projects may not require TCEQ permitting or dam safety approval.

City of Killeen acceptance of ownership of TCEQ permitted dams and impoundments will shift TCEQ compliance requirements (periodic inspections, annual reporting, etc.) to the City. Some cities include extensive language in their development code and platting requirements to avoid acceptance of dam and pond ownership and liability from developers. In practice, such avoidance usually shifts ongoing maintenance, liability, and TCEQ reporting to a property owners association after the project developer has sold off the development properties. Maintenance and reporting by a property owners association can be problematic; so many cities eventually take over such projects to ensure ongoing project performance, maintenance and public safety. Many issues related to City acceptance of dam infrastructure are political, legal and socio-economic issues that are beyond the realm of an engineering study.

11.3 DETENTION POLICY

Development of watersheds often increases downstream discharges, flooding, and channel erosion. Impervious surfaces associated with development also collect pollutants and discharge them downstream during rainfall events. The City of Killeen currently does not have formal detention requirements to reduce these development impacts. The City's staff currently identifies the need for detention on a site by site basis; however, modification to the code and drainage design criteria must require that proposed developments assess downstream impacts and detention considerations. TPDES Phase II Storm Water regulations, once formalized by TCEQ, will require the City of Killeen address storm water runoff from re-development and new development. Development of detention criteria could address TPDES water quality requirements as well as reduce the effects of development on downstream discharges, flooding, erosion, and pollution transport.

Evolving practice in other jurisdictions includes the following typical detention requirements:

- The provision for water quality storage, with a water quality volume equal to 0.5 inches to 1.5 inches of runoff times the area draining to the detention pond. This volume of storage is normally infiltrated slowly into the soil comprising the pond bottom after a rainfall event.

- The provision for channel protection storage with a volume sufficient to store the runoff from the 1-year return period storm for a time period of 24 hours. This volume of water is discharged slowly through a small pond outlet at a metered rate to ensure that downstream channels are not eroded by frequent storm events.

- The provision for so-called "whole hydrograph" detention that requires that the post development discharge from multiple storm events (such as the 1-year, 10-year and 100-year return period events) be detained to reduce the pond outflow rates to less than pre-development discharge rates. This storage is designed to protect downstream structures and flood control facilities.

The detention policy outlined above is rapidly becoming standard practice in other jurisdictions and is very responsive to various regulatory requirements. It provides the most benefit to the City for the protection of existing drainage infrastructure, the reduction of flooding and the protection of water quality.

However, there are numerous complex issues involved in the establishment of such a comprehensive policy. Many issues that must be resolved are political, legal and socio-economic issues that are beyond the realm of an engineering study. Most jurisdictions that adopt such policies either do so in a step wise fashion over several years or engage numerous stakeholder groups to obtain buy-in to an expedited adoption and implementation process.

For that reason, we recommend that the City engage a stakeholder group as soon as possible to implement such a policy. As an alternate the City could implement a stepwise implementation approach based on some or all of the following elements:

- Detention at discretion of City Engineer
- Detention of a single event, such as the 25-year return period event
- Detention/downstream impact analysis for all non-residential development (i.e. a formal detention policy for commercial/industrial/institutional areas)
- Integrated detention for residential development
- Off-site or regional detention
- Payment in lieu of detention agreements
- Incentives for low-impact development

- Water quality storage requirements (i.e., detention of "first flush")
- A stepwise implementation of the comprehensive policy described above, beginning with adoption of detention requirements for the larger flooding events

Establishment of Detention Criteria will help mitigate increased flows from development, improve water quality, and help the City meet TPDES Phase II new development and redevelopment minimum control measure requirements.

11.4 CITY-DEVELOPER AGREEMENTS

City-developer agreements between developers and municipalities stipulate how improvements built by a developer are conveyed to the municipality. The City of Killeen's city-developer agreements cover the developer's construction of infrastructure and subsequent transfer of ownership and maintenance to the City. The city-developer agreement must require construction of infrastructure to City design standards and a warranty period to ensure the infrastructure is functioning as designed. After the warranty period, ownership and maintenance responsibilities of the infrastructure would be transferred from the developer to the City. This frees the developer of on-going maintenance and allows the City to provide city-wide infrastructure management. It is imperative that the City require that the infrastructure be designed and constructed to City standards so that new infrastructure does not become a liability to the City and require repairs or replacement by the City.

11.5 REGIONAL PARTICIPATION

The City of Killeen is located at the upper reaches of the Nolan Creek, Trimmier Creek, Reese Creek, and Rock Creek watersheds. The majority of runoff that flows through the city comes from rainfall within the city limits; however, portions of the Nolan Creek watershed drain the Fort Hood U.S. Military Reservation. Runoff from Fort Hood flows into South Nolan Creek, Valley Ditch, Stewart Ditch, Liberty Ditch, Long Branch, and Caprice Ditch. For the City of Killeen to effectively manage runoff from these streams, the City must identify the storm water management activities Fort Hood conducts. Regional participation with Fort Hood would help the City of Killeen manage the Nolan Creek watershed upstream from the city limits and control water quantity and quality that flows into the city.

Because the remainder of runoff is from rainfall within the city, the City of Killeen is in direct control of runoff flowing through its drainage system. However, downstream entities will have an interest in the runoff that leaves Killeen. Nolan Creek flows east into Harker Heights; Trimmier Creek, Reese Creek, and Rock Creek flow south into unincorporated Bell County to Stillhouse Hollow Lake. Harker Heights and other communities downstream, as well as other agencies and organizations (i.e. Brazos River Authority, Bell County Water Control and Improvement District (WCID #6), Lake Stillhouse Hollow Clean Water Steering Committee), could have an interest in managing these watersheds and minimizing the quantity and quality of runoff that leaves Killeen. Regional participation with downstream entities will assist the City of Killeen with implementation of storm water management projects and/or practices.

Appendix A.8

Financial Analysis
(Section 12 of 2005 DMP)

12.0 FINANCIAL ANALYSIS

12.1 DRAINAGE UTILITY RATE ADJUSTMENT

The City of Killeen's Drainage Utility was created in October 2001 to improve the function and health of the City's drainage infrastructure. The City's initial rate structure featured two rates: residential properties paid a $2.00 monthly fee, and non-residential properties paid a $4.00 monthly fee. That initial rate structure is still in place and provides an annual revenue of approximately $700,000.

Current City of Killeen Drainage Utility annual base revenue requirements are $1,167,064. Base revenue requirements include operation and maintenance costs for drainage infrastructure, drainage utility staff, and the minor CIP program. The Drainage Master Plan recommends a bond package of $8,000,000 to fund the major CIP program; the estimated annual debt service for the bond package is $567,620. This brings total revenue requirements for the City of Killeen Drainage Utility to approximately $1,734,684.

The annual revenue provided by the current drainage utility rate structure is not adequate for current needs. The current rate structure is also disproportionate. More densely developed non-residential properties typically have significantly more impact on the drainage system than residential properties. The City of Killeen will revise its drainage utility rate structure to provide needed revenue and a more equitable rate between residential and non-residential properties.

A preliminary drainage utility rate structure was prepared with the Drainage Master Plan. The rate structure is based on available parcel and billing data; however, an audit of City of Killeen water billing is required to determine the final number of parcels for each customer class and actual revenue provided.

The proposed drainage utility rate increases the number of customer classes from two (residential and non-residential) to six: residential, multi-family, and four tiers of commercial properties. The monthly rate for multi-family properties is based on the total number of units. Multi-family properties pay the base residential fee for the first unit plus a fraction of the base residential rate for each additional unit. At the request of the City Council's Water/Sewer/Drainage Committee, the top multi-family rate was capped at $150. The monthly rate for commercial properties is based on the impacts of those property types as compared to a single-family property. Commercial properties were categorized into four groups based on size of the property and impacts to the drainage system as described below.

Commercial Group 1 - Less than 326,000 sq. ft. (7.48 acres) total land area
Commercial Group 2 - Greater than 326,000 sq. ft. (7.48 acres) and less than 651,000 sq. ft. (14.94 acres) total land area
Commercial Group 3 - Greater than 651,001 sq. ft. (14.94 acres) and less than 977,000 sq. ft. (22.43 acres) total land area
Commercial Group 4 - Greater than 977,001 sq. ft. (22.43 acres) total land area

The monthly rate for residential properties was established at $3.00 per month; multi-family and commercial classes are based on multiples of this $3.00 rate. The proposed drainage utility rate structure is shown in **Table 12.1**.

Table 12.1 Proposed Drainage Utility Rate Structure

Customer Class	Monthly Rate	Monthly Revenue	Annual Revenue
Residential	$3.00	$88.950	$1,067,400
Multi-Family[1]	$3+$2.10*additional units	$24,886	$298,637
Commercial – 1st Group	$15.00	$24,750	$297,000
Commercial – 2nd Group	$45.00	$1,890	$22,680
Commercial – 3rd Group	$75.00	$1,275	$15,300
Commercial – 4th Group	$150.00	$2,850	$34,200
Total		**$144,601**	**$1,735,217**

[1] - Capped at a maximum of $150 at Water/Sewer/Drainage Committee request.

Appendix B

Schematic Evaluation Synopsis

Appendix B.1

Regional Detention CIPs

Schematic CIP Projects

Regional Detention Ponds

2005-18 –Trimmier Road Ditch

Description: This reach of Trimmier Road ditch was identified for possible regional detention in the 2005 DMP. Atkins has identified two distinct pond locations one upstream and one downstream: The upstream location would likely be best suited for offline detention and the downstream location would likely be best suited for inline channel detention. The majority of the watershed is already built out above this location. This project is downstream of CIP 2005-15 which should therefore also be included in the considerations when estimating the benefits of this project.

Perceived Benefit: Reduce Flows downstream of ponds. However, there are not a lot of reported residential property damages downstream of these schematic ponds. There are only about 16 structures in the 100-year FEMA floodplain downstream of this potential detention project. There are however, a number of Infrastructure failures identified downstream of this pond.

Summary: There does not appear to be enough available storage volume in this reach to significantly reduce the 100-year flows. However, with a possible total detention volume of 39.8 acre-ft (Table 1) there may be enough volume available to mitigate the 50-year ultimate development flow which requires at least 52 acre-ft (Table 2).

Table 1

Available Detention Volume

Schematic Regional Detention	Volume (acre-ft)
Upstream Offline Pond	18.2
Downstream Online Pond	21.6
Total	39.8

Table 2

HEC-HMS Flow Summary Table

Hydrologic Element	Drainage Area (mi^2)	Recurrence Profile	Existing Discharge (cfs)	Ultimate Discharge (cfs)	Existing Runoff Volume (acre-ft)	Ultimate Runoff Volume (acre-ft)	Volume Increase (acre-ft)
US Pond	0.84	50-Year	2,088	2,281	308	350	42
		100-Year	2,412	2,592	356	399	43
DS Pond	1.19	50-Year	2,601	2,790	446	498	52
		100-Year	2,949	3,111	513	567	53

Upstream Off Channel Pond

Total *available volume at elevation 926 is about 17.9 acre-ft*. There is not enough volume to appreciable lower the 100-year peak flows. The 100-year peak flow is approximately 2,400 cfs;

to reduce the 100-year flow by 200 cfs to about 2,200 cfs would require at least 25 acre-ft (Table 3), which is more volume than what is available. Therefore, there does not appear to be enough available volume to appreciably lower the flows. There is also not enough volume available to detain the increase in runoff volume due at ultimate development.

Table 3
Capped Flow and Volume

Capped Flow (cfs)	Capture Volume (acre-ft)
2,200	25.38

Downstream Off Channel Pond

Total *available volume at elevation 898 is about 21.5 acre-ft*. The 100-year peak flow is about 2,900 cfs; in order to lower the flow by 200 cfs to 2,700 cfs would require at least 35 acre-ft of storage (Table 4), which is more volume than what is available. Therefore, there does not appear to be enough available volume to appreciably lower the flows. There is also not enough volume available to detail the increase in runoff volume due at ultimate development.

Table 4
Capped Flow and Volume

Capped Flow (cfs)	Capture Volume
2,700	35.16

Table 5
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
Med	2	0	2	1	1	6	$945,100

Legend

- ★ Infrastructure Failures from Sept '10
- Approx. Proposed Countours Schematic
- Existing 2-ft Contours
- Drainage Easement

0 150 300 Feet

N

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2005-18 Trimmier Road Ditch Detention

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch =150 feet
Prepared by: D. Harris	Date: May 2005
File: 2005-18Detention - Trimmier Road Ditch 11X 17.mxd	

2012-08 –Little Nolan Creek at Old Florence Ditch

Description: Approximately 4.3 square miles drains to the confluence of Little Nolan Creek and Old Florence Ditch. There are a number of undeveloped tracts, and regional detention at this location might offer a way to mitigate for ultimate conditions flow, or perhaps to reduce existing conditions flow. This site is already mostly within the 100-year floodplain. Therefore, to create storm water detention would require 1) excavation of earth and/or 2) construction of an embankment to back up water to increase storage.

The 100-year ultimate build-out watershed conditions is expected to add 350 acre-ft of runoff at this location (Table 6). Approximately 260 acre-ft of storage volume might be created through soil excavation, which would be sufficient to lower the 100-year flow by 19% (Table7). Additional floodplain storage volume might be obtained by creating an embankment at Little Nolan Road to back up water and create additional storage volume by increasing the backwater elevation. On-channel detention with an overflow elevation of approximately 826 ft appears feasible without causing significant backwater impacts. Backwater impacts could be offset with drainage easement acquisition and possible upstream improvement.

Alternatively, off-channel detention might also be considered, but the stream may require channelization to pass the low flows or the noncritical flood flows to preserve volume for the higher flows. And off-channel detention would likely require more excavation than would on-channel detention. There is no drainage easement available for this site, and easement cost would be significant. Irrespective of whether the City decides to use this area for regional detention, the area within the 100-year floodplain should be considered for future easements acquisition as the adjacent land develops.

Perceived Benefit: About 108 structures in the 100-year floodplain experience flooding downstream of this site. This project has the potential to reduce existing downstream flooding conditions. Additionally, ultimate conditions flows might be regulated to not exceed existing conditions peak flow rates. There may also be some potential to combine park and detention facilities in this area.

Summary: At a minimum, the area within the 100-year floodplain should be preserved as a drainage easement for possible future uses. Otherwise, this site does provide a viable location for regional detention if storage volume were obtained by creating backwater with an online embankment. The 100-year existing conditions peak flows might be reduced by about 1,000 cfs from 8,390 cfs to approximately 7,000 cfs (19% reduction) (Table 7), or the available detention volume might be used to hold ultimate conditions flows at existing conditions levels.

Table 6

HEC-HMS Flow Summary Table

Hydrologic Element	Drainage Area (mi^2)	Recurrence Profile	Existing Discharge (cfs)	Ultimate Discharge (cfs)	Existing Runoff Volume (acre-ft)	Ultimate Runoff Volume (acre-ft)	Volume Increase (acre-ft)
Little Nolan Upper Out	2.51	50-Year	4,535	5,434	822	1,050	228
		100-Year	5,277	6,157	960	1,196	236
Old Florence Out	1.744	50-Year	2,725	3,107	618	729	112
		100-Year	3,157	3,529	716	831	115
Little Nolan DS of Old Florence	4.254	50-Year	7,214	8,496	1,441	1,779	338
		100-Year	8,390	9,647	1,677	2,026	350

Table 7

Flow Reduction by Capture Volume

Maximum Capped Flow[+] (cfs)	Capture[++] Volume 50-yr (acre-ft)	Capture Volume 100-yr (acre-ft)	Reduction in 50-year Flow (%)	Reduction in 100-year Flow (%)
7,000	39	226	3.0	19

[+] Maximum flow proposed at pond location

[++] Minimum volume of water required to achieve "proposed flow"

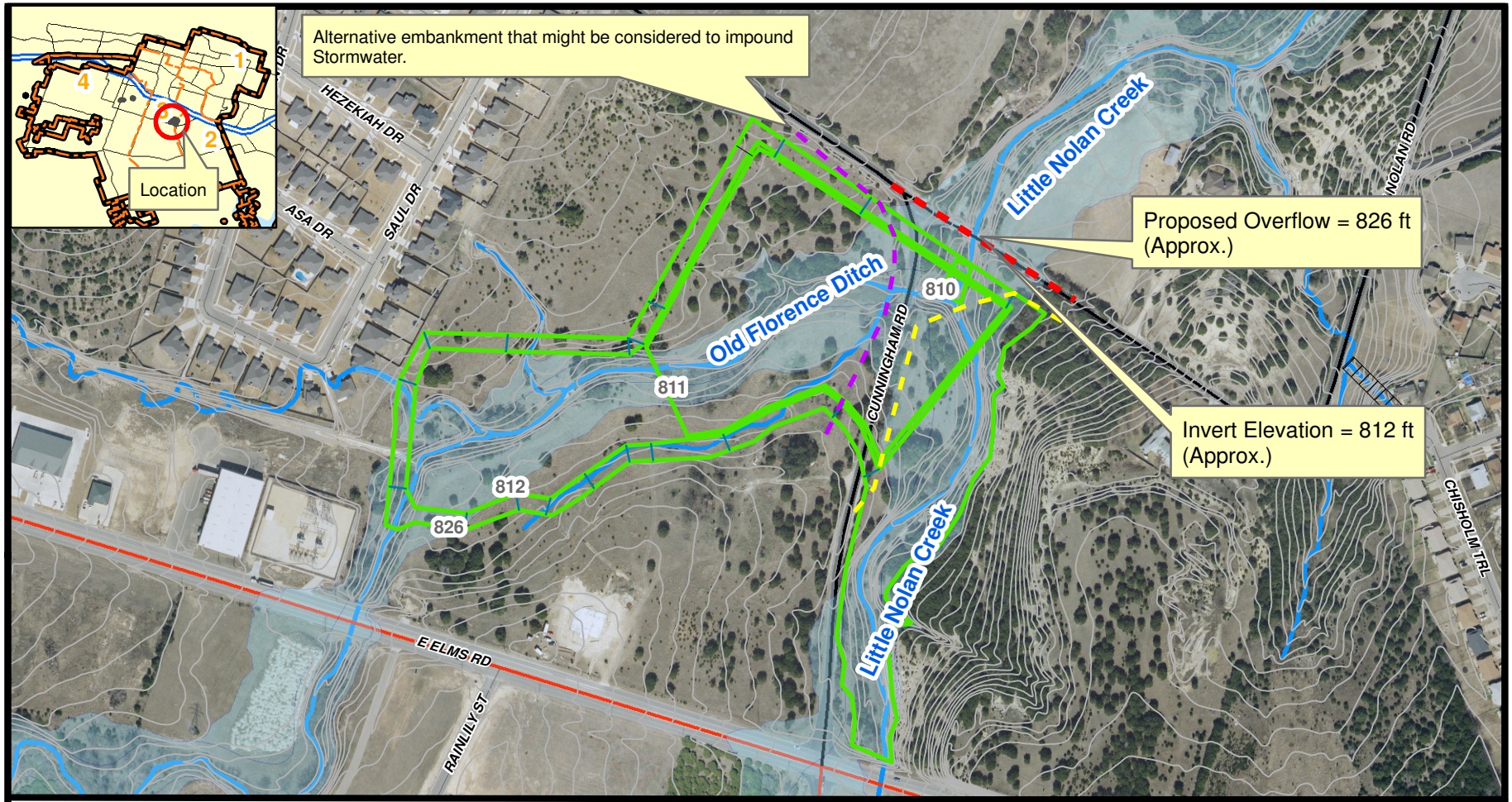
Table 8
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	$341,976	1	$341,976	
2	100	Preparing Right of Way (4%)	LS	$455,968	1	$455,968	
3	110	Excavation	CY	$20	327316	$6,546,314	Volume estimated from existing vs. proposed TIN. See: "areavol.txt" Volume below ele. 826. About 200 acre-ft.
4	132	Embankment	CY	$6	24178	$142,649	Assume 800' with approximate cross-section dimensions
5	164	Seeding for Erosion Control	SY	$2.00	77440	$154,880	Assume 16 acres
	351	Flexible Pavement Structure Repair (6")	SY	$33.00	18000	$594,000	It is assumed that Little Nolan Road will need to be raised to accommodate the outfall embankment. Assume 600'*30'
6	464	Reinforced Concrete Pipe 36 Inch	LF	$69	100	$6,900	Outfall Pipe
7	466	Headwalls and Wingwalls	EA	$10,000	1	$10,000	Outfall Wingwall
8	502	Barricades and Traffic Handling	LS	$1,500	10	$15,000	Assumed
9	506	Temporary E&S Controls	LS	$300	50	$15,000	Assumed
		Dewatering (1%)	LS	$74,847	1	$74,847	
10	--	Drainage Easement Acquisition	SF	$4.5	1,001,880	$4,508,460	Existing drainage easement only in channel
11	--	Utility Relocation (3%)	LS	$341,976	1	$341,976	Assumed
12		Engineering and Design Services (2%)	LS	$234,824	1	$234,824	
					Subtotal	$13,442,800	
					25% Contingency	$3,360,700	
					Total	$16,803,500	

Table 9

Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
Med	0	0	3	2	1	6	$16,803,500



Legend

- Drainage Easement
- Proposed Top and Bottom Pond Schmatic

100 Yr FEMA Floodplain

- Zone A
- Zone AE
- Stream Centerline
- Existing 2 ft Contours

Online Embankment Alternatives

Alternative

- Confluence of Little Nolan Creek and Old Florence Ditch
- Little Nolan Creek Emankment
- Old Florence Ditch Embankment

0 400 800 Feet

N

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2012-08 Little Nolan Creek at Old Florence Ditch

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 400 feet
Prepared by: D. Harris	Date: May, 2011
File: 2010-08 Florance Ditch and Upper Nolan at Cunningham Detention.mxd	

2005-01 Bermuda/Ronstan

Description: This pond was originally identified in the 2005 DMP. It was evaluated by Freese and Nichols (F&N) in a preliminary engineering report (PER) (October 2010). Storm water from this area flows north toward Fort Hood where it meets South Nolan Creek. The F&N PER considered two alternative ponds including:
Alternative 1 – captures flow from Bermuda/Ronstan Creek and South Nolan Creek Tributary 10,
Alternative 2 –captures flow from Bermuda/Ronstan Creek only (Table 10). F&N recommends Alternative 2 because it lowers the overtopping at Wheeler Avenue most effectively. According to the F&N PER, the 25-year flow is reduced from 1,901 to 1,242 cfs (at Junction 9 Area = 0.893 mi²), and the 100-yr flow is reduced from 2,550 to 1,941 cfs. This alterative creates about 72 acre-ft of on line detention storage.

Perceived Benefit: This project lowers the overtopping flow at Wheeler Drive so that there is almost no overtopping for the 25-year event. It is noted, however, that there is no record of Wheeler Drive being closed, even in the September 2010 event, although it might have overtopped.

Summary: At an estimated cost of almost 3 million dollars (Table 11), there does not appear to be enough benefit to justify the expense of this project. Additionally, the floodplain downstream of this project is not very extensive, and there do not appear to be any residential structures in the 100-year floodplain.

Table 10
F&N* Comparison of Design Storms and Overtopping Depths

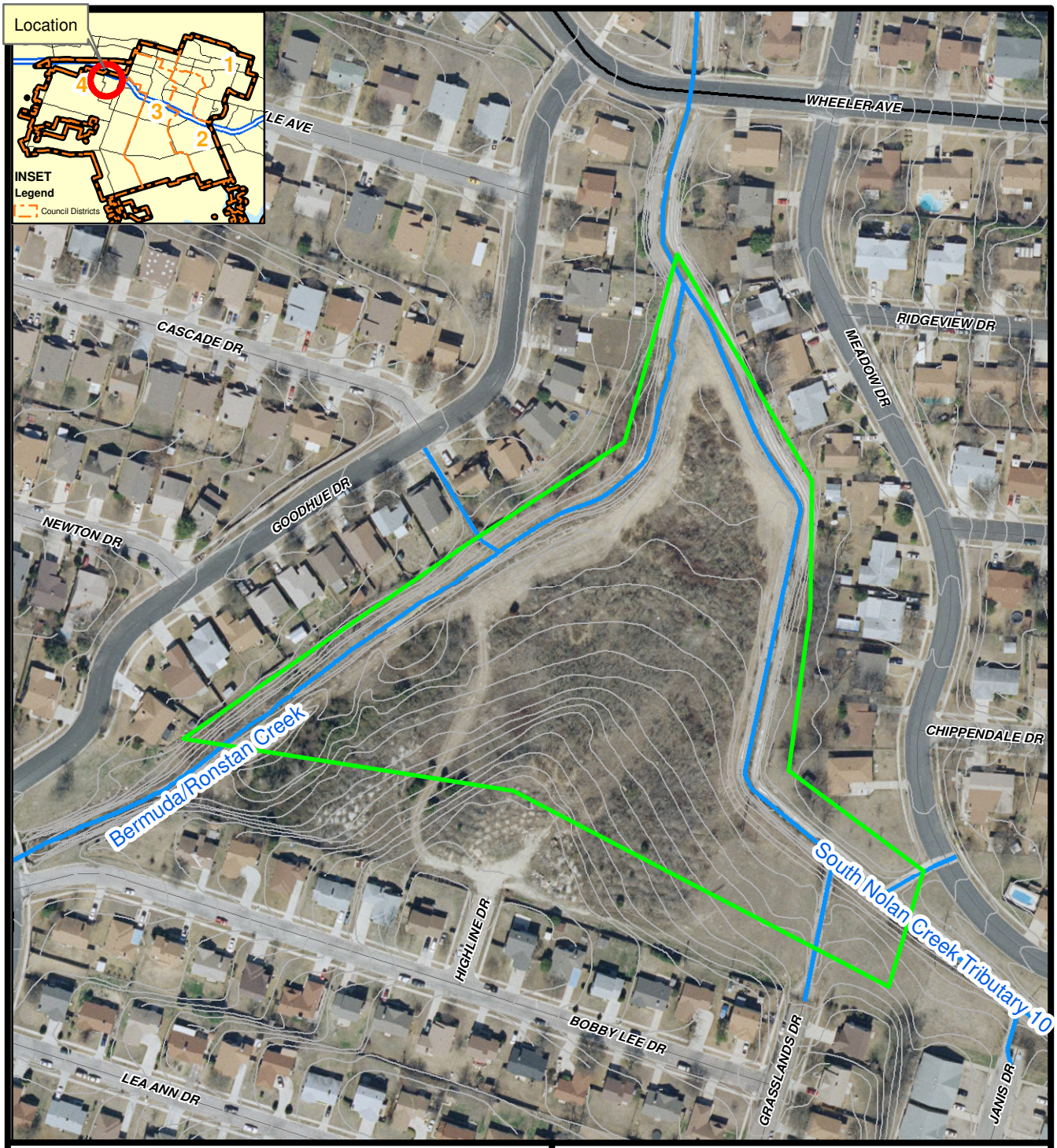
Location	Existing Conditions	Alternative 1	Alternative 2
Wheeler Avenue Design Storm (24-hour recurrence)	4-year	6-year	16-year
Wheeler Avenue 25-year Overtopping Depth	0.54 feet	0.46 feet	0.01 feet
Wheeler Avenue 100-year Overtopping Depth	1.08 feet	0.68 feet	0.59 feet

Table 11
Ranking Score and Cost Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost*
Med	2	2	0	0	1	5	$ 2,997,995

* Cost taken from F&N October 2010 PER

Figure 2005-01 Bermuda/Ronstan Detention



Legend

- Approximate Proposed Pond Outline
- Existing 2-ft Contours
- Stream Centerline

0 200 400 Feet

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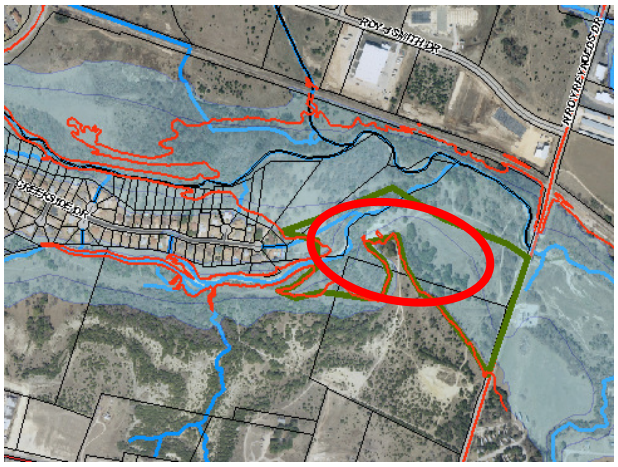
2005-01
Bermuda/Ronstan Detention

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 200 feet
Prepared by: D. Harris	Date: May 2010
File: 2005-01 Bermuda Ropnstan Detention.mxd	

2012-09 Little Nolan Creek at Outlet



Description: Approximately 11.1 square miles drain to the outlet of Little Nolan Creek. Regional detention at this location might offer a way to mitigate for ultimate conditions flow, or perhaps to reduce existing conditions flow. This site area is already mostly within the 100-year floodplain. Therefore, to create storm water detention would require either: 1) excavation of earth and/or 2) construction of an embankment to back up water to increase storage.

The 100-year ultimate build-out watershed conditions is expected to add 611 acre-ft of runoff at this location (Table 12). Approximately 413 acre-ft of storage volume might be created through soil excavation (Table 14). Additional floodplain storage volume might be created by creating an embankment at North Roy Reynolds Drive to create additional storage volume by increasing the backwater elevation. On-channel detention would likely cause backwater impacts to upstream properties. These impacts might be addressed with drainage easement acquisition and possible upstream improvement.

Off-channel detention likely would not be feasible, because the area is already in the floodplain so any added storage could only be created through excavation. There is no drainage easement available for this site, and easement cost would be significant. Irrespective of whether the City decides to use this area for regional detention, the area within the 100-year floodplain should be considered for future easements acquisition as the adjacent land develops.

A levee system would likely be required to keep out flows from South Nolan Creek.

Perceived Benefit: Significant flooding occurs on South Nolan Creek downstream in the City of Belton. Regional detention at this location might be used to either reduce existing conditions flood flows, or it might be used to mitigate ultimate development flows to maintain existing conditions peak flow. This would have a public relations benefit for the City of Killeen. This location also provides a convenient location to control storm water due to existing impervious cover and future ultimate conditions flows This project would offer good public relations and good neighbor regional type benefit only. As such, funding outside of the City of Killeen might be explored.

Summary: This project would likely require a significant amount of excavation to avoid significant backwater impacts. It is likely that this project would only be feasible by creating storage volume by raising the water surface elevation with an embankment and levee system. Given the cost and complexity, this project is only considered to have moderate feasibility. Depending on how much volume might be obtained through backwater storage (using an embankment), this site may be considered feasible. However, a detailed flood control study would be required to determine this.

Table 12

HEC-HMS Flow Summary Table

Hydrologic Element	Drainage Area (mi^2)	Recurrence Profile	Existing Discharge (cfs)	Ultimate Discharge (cfs)	Existing Runoff Volume (acre-ft)	Ultimate Runoff Volume (acre-ft)	Volume Increase (acre-ft)
Little Nolan Outlet	11.1	50-Year	16,257	17,972	4,037	4,629	592
		100-Year	18,692	20,334	4,662	5,274	611

Table 13

Flow Reduction by Capture Volume (100-year)

Proposed Peak Flow+ cfs)	Capture Volume ++ 100-yr (acre-ft)
16,000	454

+ Maximum flow allowed at pond location

++ Minimum volume of water required to achieve proposed peak flow

Table 14

Flood Control Dimensions

Added Flood Control Volume (acre-ft)	413
Overflow Elevation (ft)	754

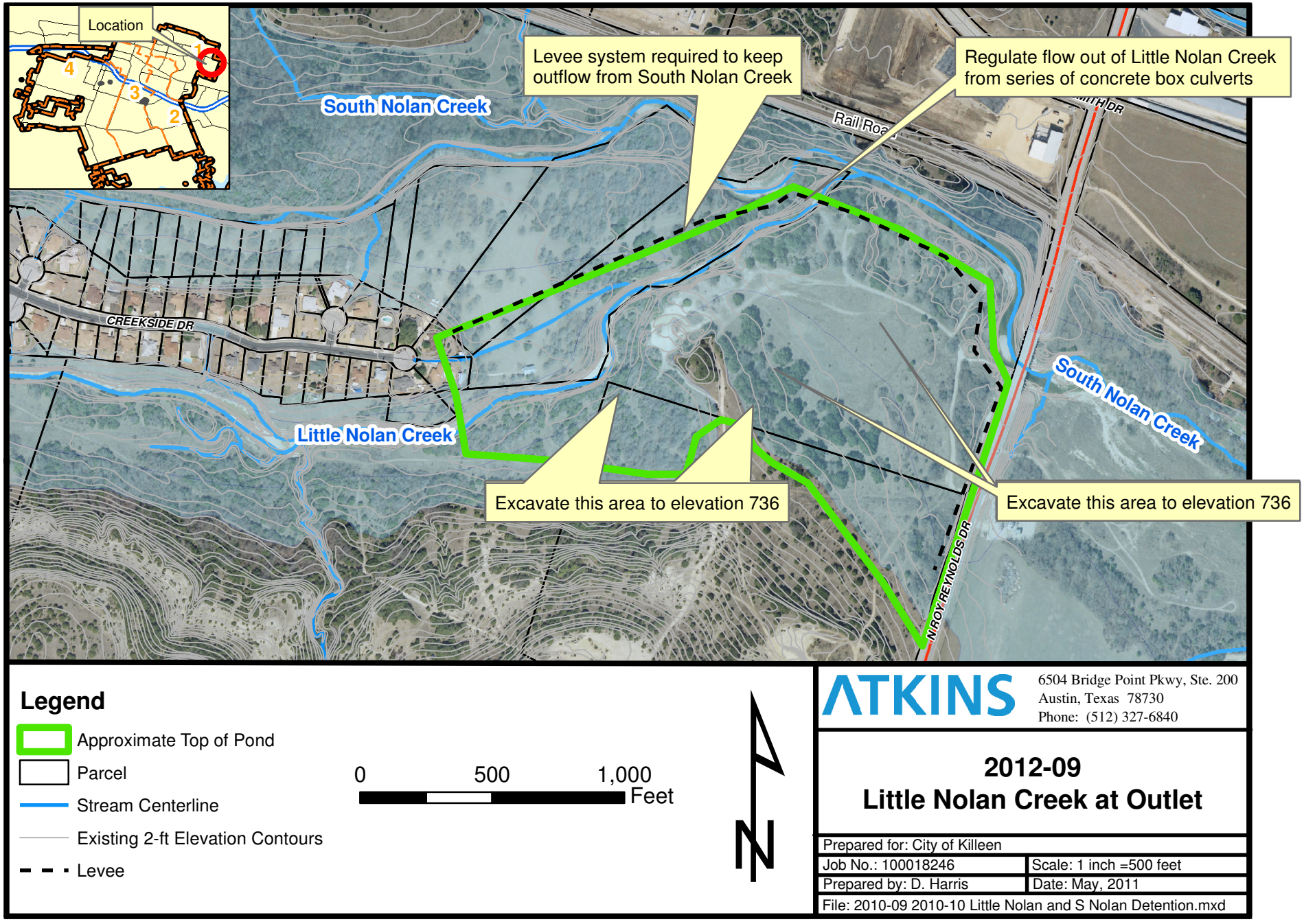
Table 15

Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	$560,812	1	$560,812	
2	100	Preparing Right of Way (5%)	LS	$934,686	1	$934,686	
3	110	Excavation	CY	$20	405,431	$8,108,629	Volume estimated from existing vs. proposed TIN. See: CIP Locations\ Raster: CUTFILLA
4	132	Embankment	CY	$6	35,556	$209,778	Assumed Embankment to separate flows between South Nolan and Little Nolan Creek, and to raise N. Roy Reynolds Drive
5	164	Seeding for Erosion Control	SY	$2.00	154,880	$309,760	Assume 32 acres
6	351	Flexible Pavement Structure Repair (6")	SY	$33.00	7,111	$234,667	Assume 1600 ft of Road improvement along N. Roy Reynolds Drive
7	462	Concrete Box Culverts (1-10'x4')	LF	375	600	$225,000	Assumed due to outfall at Roy Reynolds Drive and outfall from detention
8	466	Headwalls and Wingwalls	EA	$10,000	6	$60,000	Outfall Wingwall
9	502	Barricades and Traffic Handling	LS	$1,500	10	$15,000	Assumed
10	506	Temporary E&S Controls	LS	$300	100	$30,000	Assumed
11		Dewatering (1%)	LS	$91,928	1	$91,928	
12	--	Drainage Easement Acquisition	SF	$4.5	2,090,880	$9,408,960	Assume 48 acres
13	--	Utility Relocation (3%)	LS	$560,812	1	$560,812	Assumed
14		Engineering, Surveying and Permitting Services (3%)	LS	$577,636	1	$577,636	Assumed
					Subtotal	$21,327,700	
					25% Contingency	$5,331,900	
					Total	$26,659,600	

Table 16
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
Med	0	0	3	1	0	4	$26,659,600



Legend

- Approximate Top of Pond
- Parcel
- Stream Centerline
- Existing 2-ft Elevation Contours
- Levee

0 500 1,000 Feet

N

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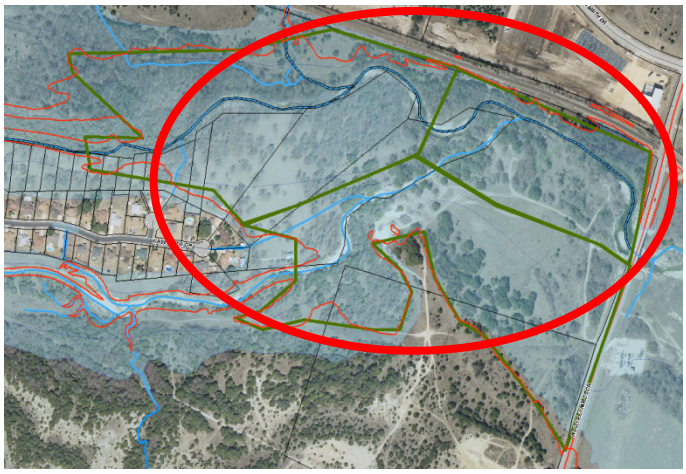
2012-09
Little Nolan Creek at Outlet

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch =500 feet
Prepared by: D. Harris	Date: May, 2011
File: 2010-09 2010-10 Little Nolan and S Nolan Detention.mxd	

2012-10 South Nolan Creek and Little Nolan Creek at Confluence



Description: This site is at the confluence of South Nolan and Little Nolan creeks and Roy Reynolds Drive. Approximately 57% of the City drains to this location. The majority of this site area available for regional detention is already occupied by floodplain. Therefore, the only way to create detention volume without causing backwater is to excavate the overbanks. It is estimated that 560 acre-ft of floodplain storage might be created through relatively extreme excavation. However, if the backwater elevation could be increased in this area, then impounding water with an embankment (instead of excavation) would be the most cost effective and environmentally conservative method to create storm water detention. The site area is approximately 80 acres. If 560 acre-ft could be excavated, the 100-year flows might be lowered from 45,706 cfs to 42,299 cfs (tables 18). The volume increase from existing to ultimate conditions is estimated to be 1,746 acre-ft (see Table 17), and about half this volume might be offset through excavation.

It's conceivable that this pond could be built using embankment only, which would be far more cost effective and environmentally conservative because floodplain storage is created by increasing the water surface elevation instead of excavation. However, it is not clear if backwater impacts are tolerable. Given the close proximity of residential property, a levee system would be required to protect existing property against increased inundation if an embankment without excavation were used to impound floodwater. Additionally, there are train tracks just north of the site at an elevation of 756 ft, and the invert of the regional detention pond would be at about 728 ft elevation. The overflow elevation might be placed at about 754 ft in elevation if provisions were made to raise N. Roy Reynolds Drive, and possibly raise or develop a floodwall/levee around the rail and/or upstream property to protect it.

Perceived Benefit: Significant flooding occurs on South Nolan Creek downstream in the City of Belton. Regional detention at this location might be used to either reduce existing conditions flood flows, or it might be used to mitigate ultimate development peak flows to maintain existing conditions peak flow levels. This would have a public relations benefit for the City of Killeen. This location also provides a convenient location to control storm water due to existing impervious cover and future ultimate conditions flows since it is at the outlet of the City draining the majority of the flows from Killeen. And finally, this area might offer park area and preserve in conjunction with detention.

Summary: This project would require significant earth-moving and embankment construction activities. However, some combination of excavation and levees might be considered to optimize flow reduction per unit cost. As this area is already in the FEMA floodplain, it likely will not be developed in the future. As such, it offers an attractive location that might be used to control flood flows, and possibly include park area and/or nature preserve. Depending on how much volume might be obtained through backwater storage

(using an embankment), this site may be considered feasible. However, a detailed flood control study would be required to ascertain this.

Table 17
HEC-HMS Flow Summary Table

Hydrologic Element	Drainage Area (mi^2)	Recurrence Profile	Existing Discharge (cfs)	Ultimate Discharge (cfs)	Existing Runoff Volume (acre-ft)	Ultimate Runoff Volume (acre-ft)	Volume Increase (acre-ft)
S Nolan US of Lit Nolan	26.6	50-Year	23,796	25,872	7,886	8,984	1,098
		100-Year	27,267	29,259	9,106	10,231	1,125
Little Nolan Outlet	11.1	50-Year	16,257	17,972	4,037	4,629	592
		100-Year	18,692	20,334	4,662	5,274	611
S Nolan DS of Lit Nolan	37.7	50-Year	39,800	43,626	11,930	13,613	1,683
		100-Year	45,706	49,441	13,758	15,505	1,746

Table 18
Flow Reduction by Capture Volume (100-year)

Proposed Peak Flow+ (cfs)	Capture Volume++ 100-yr (acre-ft)
42,299	560
43,000	441

[+] Maximum flow proposed at pond location
[++] Minimum volume of water required to achieve "proposed flow"

Table 19
Flood Control Dimensions

Additional Flood Control Volume (acre-ft)	560
Overflow Elevation (ft)	754

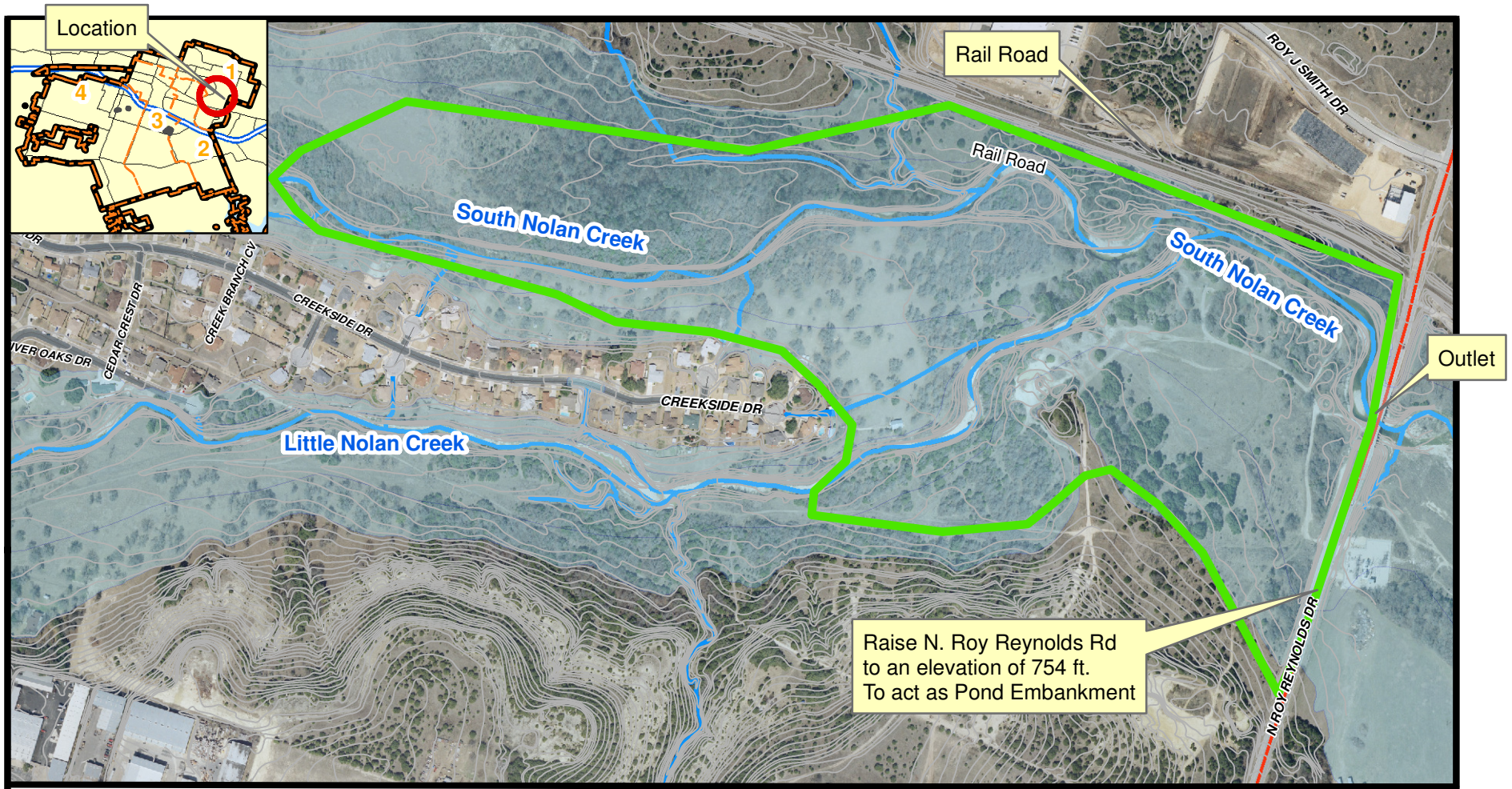
Table 20
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	$1,181,856	1	$1,181,856	
2	100	Preparing Right of Way (5%)	LS	$1,969,760	1	$1,969,760	
3	110	Excavation	CY	$20	905247	$18,104,946	Volume estimated from existing vs. proposed TIN. See: CIP Locations\ Raster: CUTFILLB
4	132	Embankment	CY	$6	17778	$104,889	Assumed embankment to raise N. Roy Reynolds Drive
5	164	Seeding for Erosion Control	SY	$2.00	488840	$977,680	Assume 101 acres
	351	Flexible Pavement Structure Repair (6")	SY	$33.00	7111	$234,667	Assume 1600 ft of road improvement along N. Roy Reynolds Drive
6	462	Concrete Box Culverts (1-10'x4')	LF	150	600	$90,000	Assumed due to outfall at Roy Reynolds Drive and outfall from detention
7	466	Headwalls and Wingwalls	EA	$10,000	4	$40,000	Outfall Wingwall
8	502	Barricades and Traffic Handling	LS	$1,500	10	$15,000	Assumed
9	506	Temporary E&S Controls	LS	$300	100	$30,000	Assumed
10	--	Drainage Easement Acquisition	SF	$4.5	4399560	$19,798,020	Assume 101 acres
11	--	Utility Relocation (3%)	LS	$1,181,856	1	$1,181,856	Assumed
12		Engineering, Surveying and Permitting Services (1%)	LS	$405,771	1	$405,771	Assumed
					Subtotal	$44,134,400	
					25% Contingency	$11,033,600	

Total $55,168,000

Table 21
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
Med	0	0	3	1	0	4	$55,168,000



Legend

- Approx. Extent of Grading
- Top of Pond_2010-09
- Stream Centerline
- Contours Grey

0 600 1,200 Feet

N

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2012-10
South Nolan at Little Nolan Conofluence Detention

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch =600 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-09 2010-10 Little Nolan and S Nolan Detention.mxd	

2005-03 Upper Stewart Ditch

Site Description: This site is just downstream of Fort Hood. The total available detention volume is only about 15.2 acre-ft. As shown in tables 18 and 19, almost 19 acre-ft would be required to lower the 50-year flow from 1,626 to about 1,500 cfs (Table 22). It would require about 53 acre-ft to reduce the 100-year flow from 1,838 to 1,500 cfs (Table 23), which is far more detention volume than can be obtained from this site. This site's location is probably best suited as an offline detention pond with a side overflow weir system that can be used to shave off the peak flow volume. See CIP 2012-11 for information on the downstream infrastructure repairs proposed for Stewart Ditch. The only drainage easement is within the channel, and a significant amount of drainage easement would need to be acquired within the pond footprint

Perceived Benefit: There is a significant amount of downstream flooding based on the FEMA 100-year floodplain. There are 103 structures in the Stewart Ditch 100-year FEMA floodplain (not including the structures in the floodplain due to the South Nolan Creek backwater). Additionally, there are several infrastructure failures downstream of this site from the September 2010 event. Therefore, reducing the flows at this location would also reduce the shear stress downstream and help prevent future infrastructure failures.

Summary: There is not enough detention volume at this location to significantly reduce the 100-year flow. At best, the 50-year flow might be reduced by approximately 6%. This level of benefit appears to be insufficient to justify the cost of this project.

Table 22

HEC-HMS Flow Summary

Profile	Drainage Area (mi2)	Peak Discharge (cfs)	Runoff Volume (acre-ft)
50-Year	0.625	1,626	266
100-Year		1,838	302

Table 23

Flow Reduction by Capture Volume

Proposed Peak Flow+ (cfs)	Capture Volume 50-yr (acre-ft)++	Capture Volume 100-yr (acre-ft)	Reduction in 50-year Flow (%)
1,500	18.90	53.01	6

+ Maximum flow proposed at pond location

++ Minimum volume of water required to achieve "proposed flow"

Table 24

Ranking Score and Cost Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost*
Med	2	1	0	0	0	3	$ 1,716,800

Table 25
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	$34,220	1	$34,220	
2	100	Preparing Right of Way (4%)	LS	$45,627	1	$45,627	
3	110	Excavation	CY	$20	24523	$490,453	
4	132	Embankment	CY	$6		$-	
5	164	Seeding for Erosion Control	SY	$2.00	18876	$37,752	Approximate Area of Site
6	464	Reinforced Concrete Pipe 36 Inch	LF	$69	100	$6,900	Outfall Pipe
7	466	Headwalls and Wingwalls	EA	$10,000	1	$10,000	Outfall Wingwall
8	502	Barricades and Traffic Handling	LS	$1,500	2	$3,000	
9	506	Temporary E&S Controls	LS	$300	15	$4,500	
10	--	Drainage Easement Acquisition	SF	$4.5	130680	$588,060	Existing drainage easement only in channel
11	--	Utility Relocation (5%)	LS	$57,033	1	$57,033	Assumed
12		Engineering and Design Services (8%)	LS	$95,816	1	$95,816	
					Subtotal	$1,373,400	
					25% Contingency	$343,400	
					Total	$1,716,800	

Legend

- Drainage Easement
- Parcel
- 837 Proposed Top & Bottom Pond Schematic
- Stewart Ditch Centerline
- Existing 2 ft Contours

0 200 400 Feet

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2005-03 Upper Stewart Ditch Detention

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 200 feet
Prepared by: D. Harris	Date: May, 2011
File: 2005-03 Stewart Ditch Upper Pond.mxd	

2005-15 Little Nolan Creek Tributary-1 at Caprock Drive

Description: This project was originally identified in the 2005 DMP. The schematic pond site is upstream of the two ponds proposed in CIP 2005-18, and therefore will need to be considered in conjunction with the schematic ponds considered in CIP 2005-18. A preliminary engineering study is currently under way for this project. Therefore, the ranking and cost estimates for this pond are pending the completion of that preliminary engineering report.

Perceived Benefit: Reduce flows downstream.

Summary: There are only a few homes and businesses in the FEMA 100-year floodplain downstream of this location. Recommendations for this capital improvement are pending the completion of a PER due in approximately August 2011.

Legend

- Infrastructure Failures from Sept '10
- Proposed Detention Area (2005 DMP)
- Houses in 100-yr Floodplain
- Drainage Easement
- 2 ft Elevation Contours
- Stream Centerline

0 300 600 Feet

N

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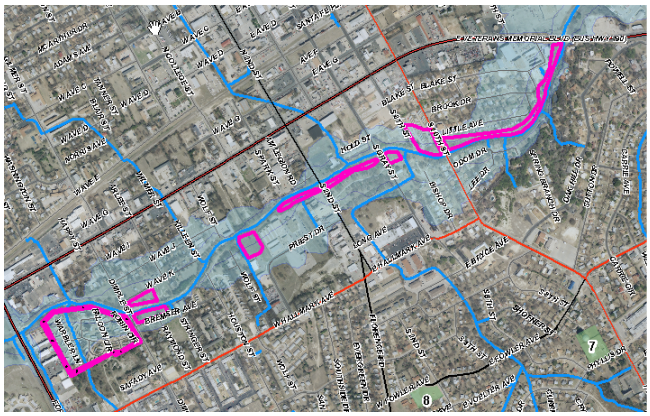
2005-15
LNC Tributary 1 at CaprockDrive Bank Stabilization and Detention

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 200 feet
Prepared by: D. Harris	Date: March, 2011
2005-15 Bank Stabilization and Detention.mxd	

2012-12 Upper South Nolan Creek

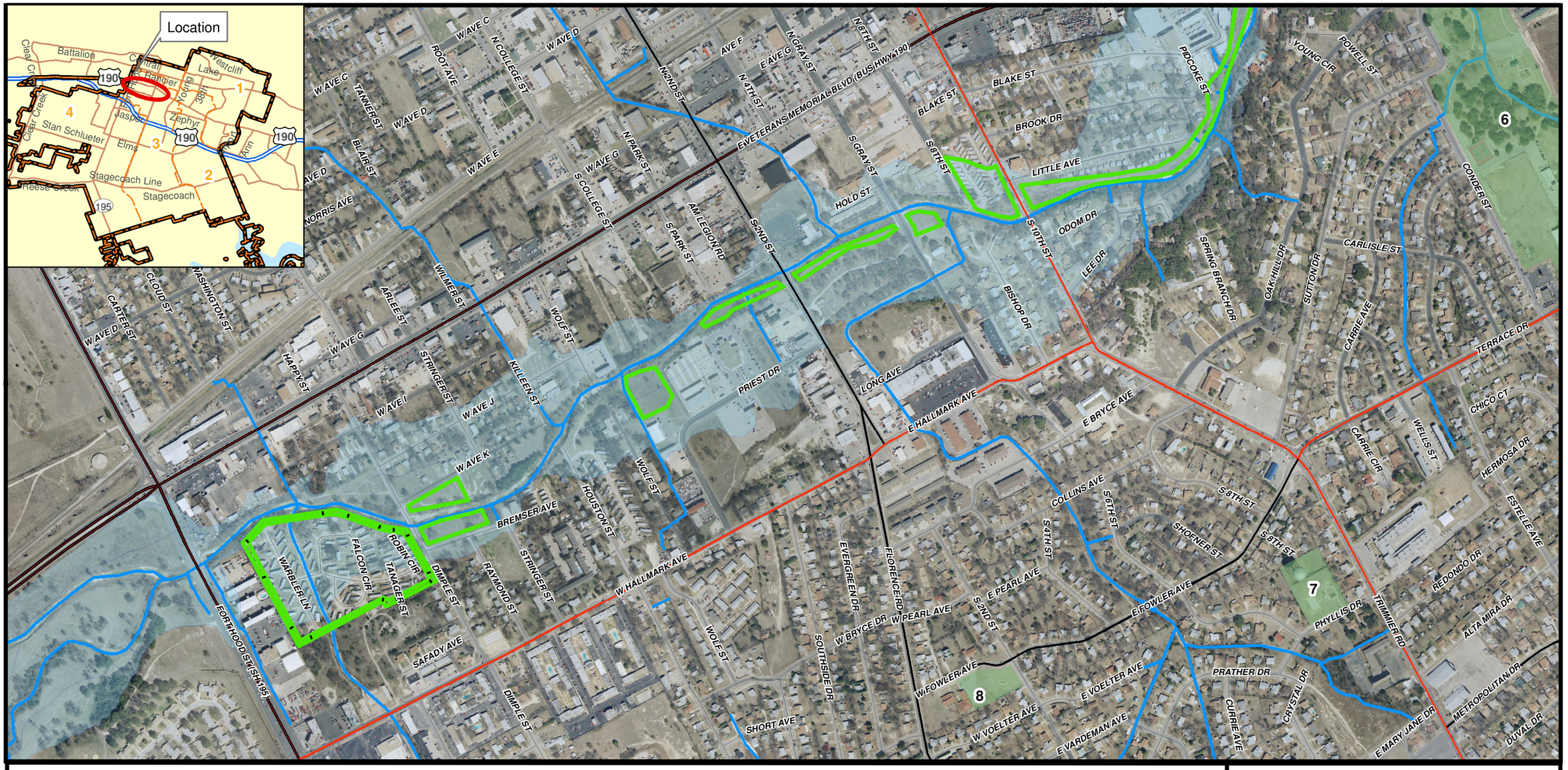


Description: Throughout this entire reach, there are about 33 acres that might be utilized for drainge improvements. If it is assumed that water could be stored an average of 5 ft deep, this would allow for an additional 160 acre-ft of storage volume. Considering that the 100-year flow through this reach is about 18,000 cfs, 160 acre-ft of storage would not appreciably lower the 100-year flows.

The Upper South Nolan reach was also considered by Jacobs Engineering for regional detention and channel grading. The Jacobs study considered regional detention at Demple Street and Gray Street, which alone would only lower the 100-year flow by 1,000 cfs. Additionally, regional detention was evaluated on Fort Hood; however, it has since been determined that detention at Fort Hood is not a viable option.

Perceived Benefit: There is a significant amount of flooding along South Nolan Creek, and any reduction in flow would be considered beneficial.

Summary: To lower flows appreciably would require a significant amount of detention, in excess of what is practicable, and detention in this area is most likely cost prohibitive.



Legend

- Conceivable Detention Area
- Floodplain (FEMA Zone AE)
- Stream Centerline

0 600 1,200 Feet

N

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2012-12 Upper South Nolan Creek Detention

Prepared for: City of Killeen	
Job No.: 100018256	Scale: 1 inch = 450 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-12 Upper South Nolan Detention.mxd	

Appendix B.2

Storm Drain and Ditch Neighborhood Drainage CIP

Schematic CIP Projects

Storm Drain and Ditch Neighborhood Drainage

Schematic Ponds

2005-27 Greenforest Circle Storm Drain and Inlets

Site Description: This site has a well-documented history of drainage issues due to the lack of a well-defined drainage course with enough flow capacity to convey the runoff to the outlet of the neighborhood in Greenforest Circle. Approximately 47.5 acres drain to the outlet of this project (the drainage area cannot be estimated precisely due to a lack of detailed topographic data; therefore, USGS 20-ft contours were used to estimate the headwater area). Based on StormCAD estimates, in order to keep the 25-year storm hydraulic grade line below ground would require approximately a 42-inch storm sewer. In addition, improvements to the existing storm sewer outfall are required.

There are no drainage easements, and some easement acquisition will likely be required if the existing storm sewer pipe at the outlet is to be improved. This project was originally proposed in the 2005 DMP; however, less storm sewer pipe was assumed in 2005 than what is proposed here. The schematic improvements presented here could be scaled back to just improve the drainage near the outfall on v Circle, although ideally the water would be intercepted at South Roy Reynolds Drive.

Perceived Benefit: At least one residential property is known to have experienced flooding in the September 2010 event. The benefit of this project would be recognized by the citizens in this neighborhood, who have long complained of the lack of drainage infrastructure. In addition, the drainage would be improved along South Roy Reynolds Drive and along Greenforest Circle, enhancing transportation access.

Summary: This project has a well-defined benefit for the estimated cost and should be considered a high priority project.

Table 1
Runoff Estimate (Rational Method)

Drainage Area	Drainage Area (acres)	2-Yr	10-Yr	25-Yr	50-Yr	100-Yr
		(cfs)				
1	30.1	62	90	116	138	162
2	17.5	37	54	70	83	98
Total	47.5	99	144	186	221	259

Table 2
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	2	3	5	4	0	14	$208,400

Table 3
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	3,739	1	3,739	
2	100	Preparing Right of Way (4%)	LS	4,985	1	4,985	
3	110	Excavation	CY	20	503	10,056	
4	164	Seeding for Erosion Control	SY	2	4,500	9,000	Assumed 150' X 30' for outfall channel
	351	Flexible Pavement Structure Repair (6")	SY	33	302	9,955	Assumed 905' X 3'
5	402	Trench Excavation Protection	LF	3	1,045	3,135	Including storm sewer pipe along outfall
6	462	Reinforced Concrete Pipe 42 Inch	LF	75	1,045	78,375	Including storm sewer pipe along outfall
7	466	Headwalls and Wingwalls	EA	10,000	1	10,000	Outfall
8	465	Curb Inlet (TY II) (15')	EA	3600	1	3,600	Assumed inlet size
9	465	Curb Inlet (TY II) (20')	EA	5000	2	10,000	Assumed inlet size
10	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
11	506	Temporary E&S Controls	LS	300	2	600	
12	--	Outfall Armoring	EA	2,000	1	2,000	
13	--	Drainage Easement Acquisition	SF	5	4,380	19,710	Assuming storm sewer can be laid in public ROW except for the 146-ft outfall reach
14	--	Utility Relocation (5%)	LS	0	4,380	0	
15		Engineering and Design Services (8%)	LS	9,970	1	9,970	
					Subtotal	166,700	
					25% Contingency	41,700	
					Total	208,400	

Legend

- Storm Drainage Inlet
- Storm Sewer Pipe
- House Flooding
- Existing 2 ft Elevation Contours
- City Limits
- 820 USGS 20 ft Elevation Contour
- Drainage Area
- Enlarge Outlet Storm Sewer Pipe

0 400 800 Feet

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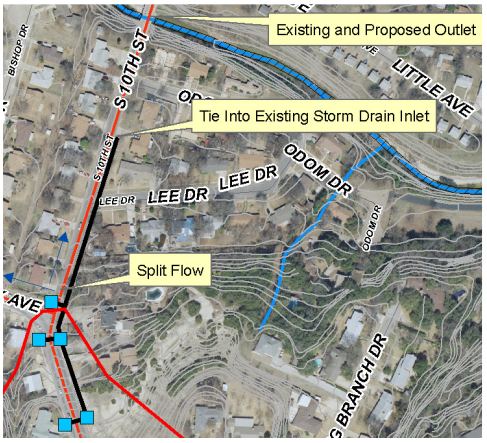
2005-27 Greenforest Circle Neigborhood Drainage

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 400 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005-27 Greenforest Circle Neigborhood Drainage.mxd	

2012-21 Trimmier/10th Street at Hallmark Storm Drain and Inlets



Site Description: About 9.7 acres of area drains to the intersection of South 10th Street and East Hallmark Avenue, generating a 25-year flow of approximately 65 cfs (Table 4). The flow splits at Hallmark Avenue. Part of it flows west (down Hallmark Avenue), and the remainder flows north (down South 10th Street). This intersection is known to have a significant amount of inundation and generally creates a traffic hazard. It is recommended that storm sewer pipe and curb inlets be added to capture runoff before it inundates the intersection. The storm sewer system may then be tied in to an existing storm drain line on South 10th Street.

Perceived Benefit: By removing water from the road, traffic safety will be improved significantly and transportation access will be increased as well.

Summary: This project is considered a high priority with high ranking in public safety, transportation access, and engineering economy (Table 5), and should be considered a high priority drainage project.

Table 4

Runoff Estimate (Rational Method)

Drainage Area	Area (acres)	2-Yr	10-Yr	25-Yr	50-Yr	100-Yr
		(cfs)				
1	9.7	35	51	65	78	91

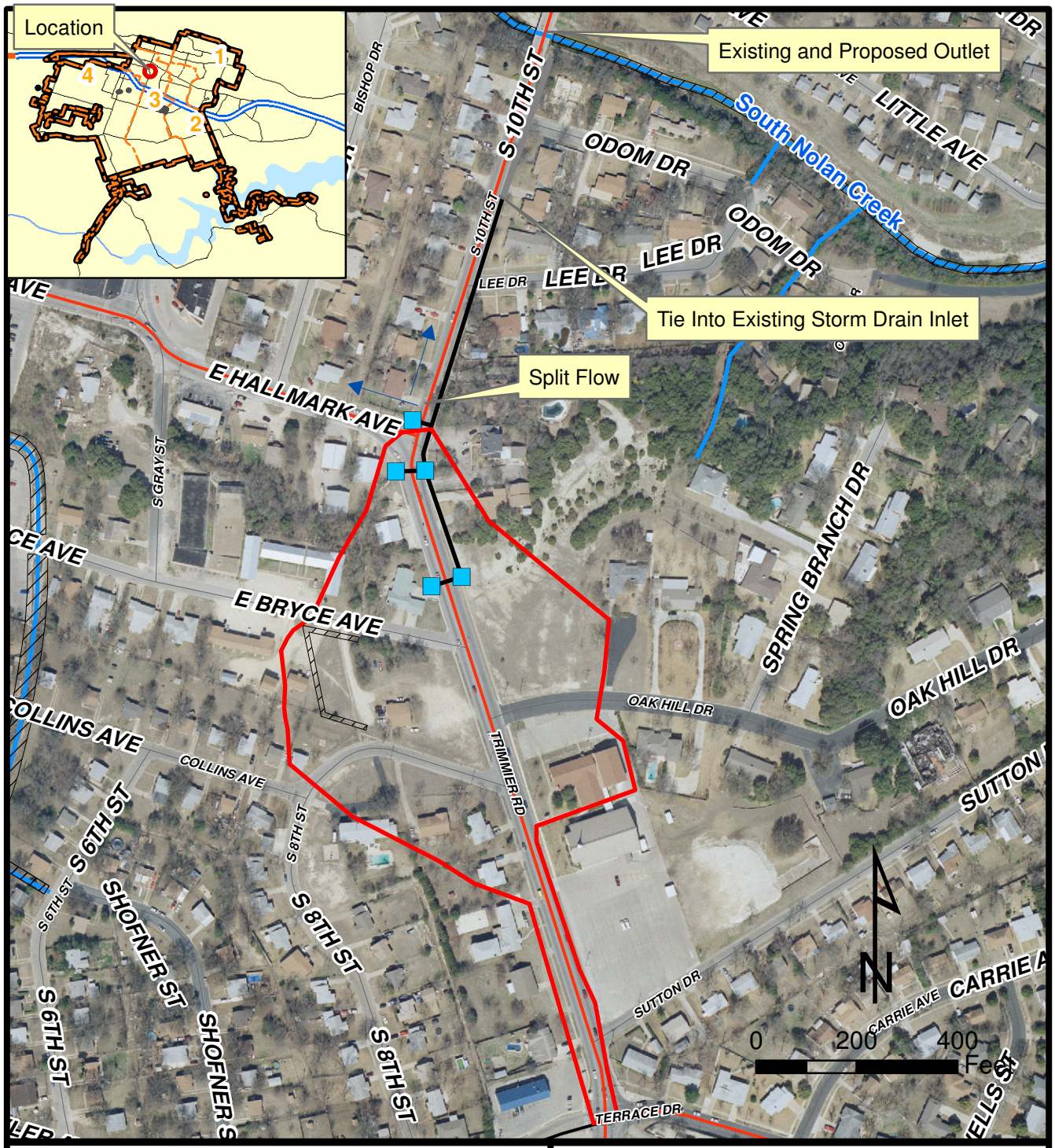
Table 5

Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	5	5	1	4	0	15	$201,300

Table 6
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	4,052	1	4,052	
2	100	Preparing Right of Way (4%)	LS	5,402	1	5,402	
3	110	Excavation	CY	20	525	10,500	Assumed = 945*5*3/27
4	351	Flexible Pavement Structure Repair (6")	SY	33	1050	34,650	Assume = 945 ft X 10 ft. However, there may be enough transportation ROW so that it is not necessary to rebuild road.
5	402	Trench Excavation Protection	LF	3	945	2,835	Assumed
6	462	Reinforced Concrete Pipe 42 Inch	LF	75	945	70,875	
7	465	Curb Inlet (TY II) (10')	EA	2700	2	5,400	Assumed inlet dimension
8	465	Curb Inlet (TY II) (15')	EA	3600	3	10,800	Assumed inlet dimension
9	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
10	506	Temporary E&S Controls	LS	300	4	1,200	
11		Engineering and Design Services (10%)	LS	13,776	1	13,776	
					Subtotal	$ 161,000	
					25% Contingency	$ 40,300	
					Total	$ 201,300	



Legend

- Drainage Area
- Drainage Easement
- Inlet
- Proposed Storm Sewer
- Stream Centerline
- Existing Storm Sewer

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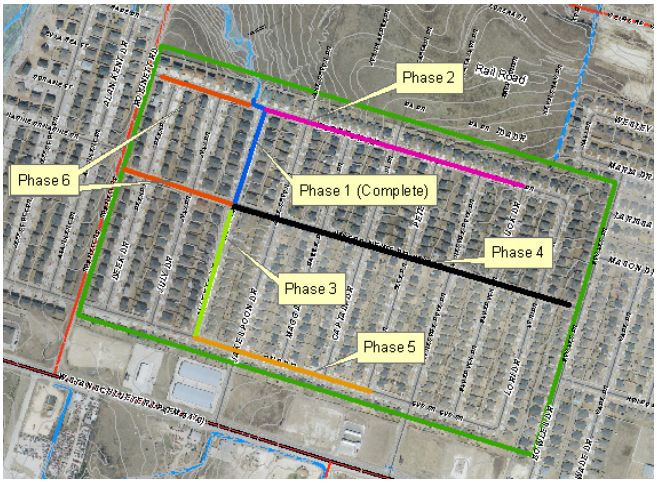
2012-21
Trimmier 10th Street at Hallmark Street Drainage

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 300 feet
Prepared by: D. Harris	Date: April, 2011
File: 2010-21 Trimmier 10th Street at Hallmark Drainage.mxd	

2012-02 Woodrow – Phase 2 Storm Drain Construction



Site Description: This neighborhood discharges at Woodrow Drive. The existing infrastructure is insufficient to cope with the runoff that is being concentrated at the discharge point. Approximately 134 acres drain to the Woodrow Outlet, with a 25-year flow of about 609 cfs (Table 7). The top of curb is exceeded for even very minor storm events, so much so that the fill behind the curb is being stripped away. Frequent storms make Woodrow Drive impassable by sedan-type vehicles. Recently, a study was performed by Walker, Wiederhold, and Associates that recommended improving the drainage outlet and additional phases of storm sewer construction. A total of six phases was recommended. The first phase including the outlet and first reach of storm sewer has been constructed. The second phase provides storm sewer improvements from the outlet eastward on Woodrow Drive. The entire cost to construct all phases of the project was estimated to be $1,660,607. The estimated cost for phase 2 is about $330,300 (Table 8).

Perceived Benefit: Collect water off of residential streets, thereby alleviating nuisance flooding and improving egress and regress through the neighborhood. This area is densely populated, and the improvements would be recognized by the citizens as a useful drainage project.

Summary: Phase 1 has already been constructed, and additional phases are necessary to alleviate flooding in this neighborhood. Phase 2 has a high engineering economy and improves transportation access and should be considered high priority.

Table 7
Flow Est. Walker, Wiederhold, and Associates

Area (acres)	10-Yr	25-Yr	100-Yr
	(cfs)		
134	512	609	757

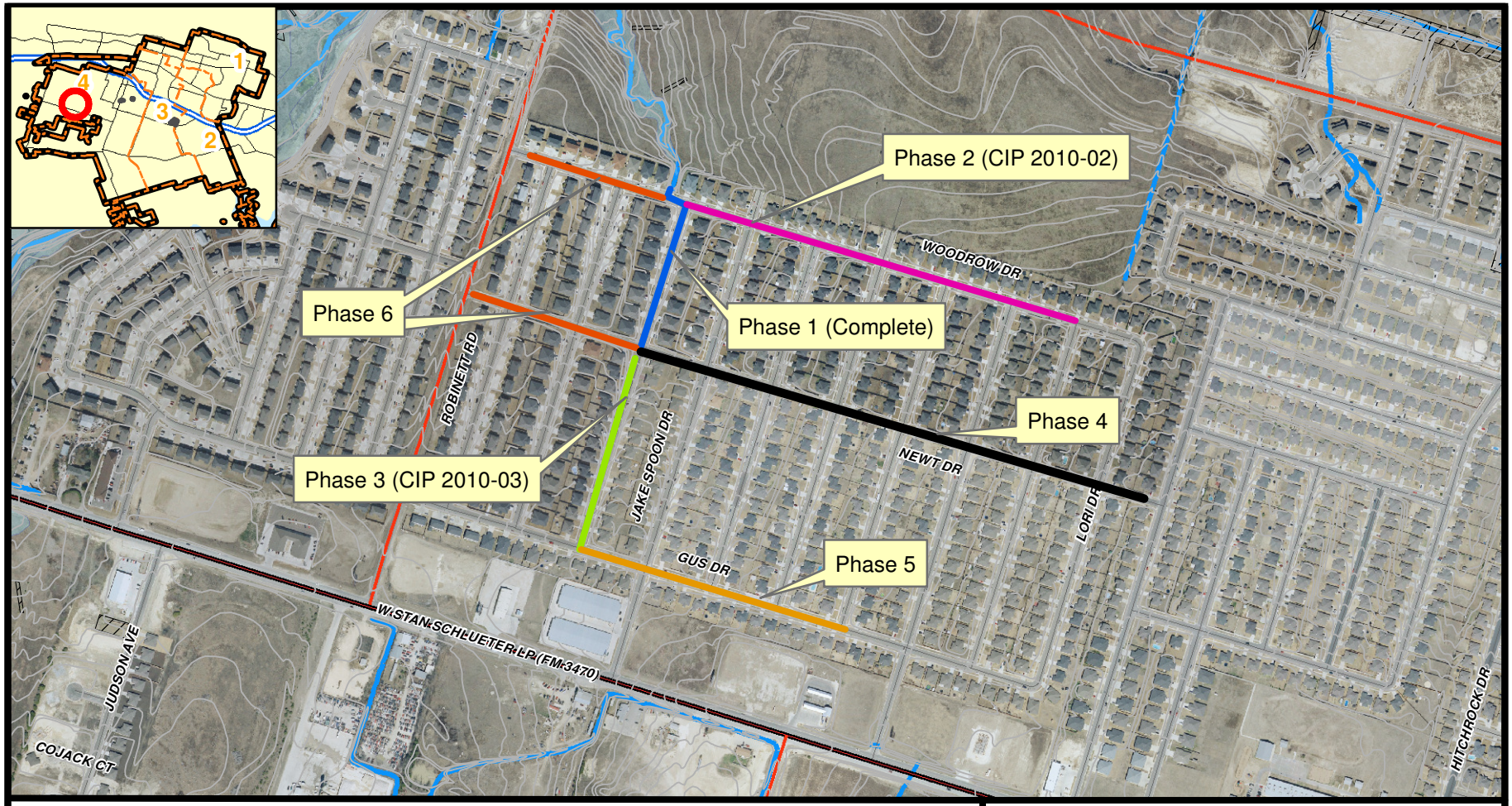
Table 8
Phase 2 Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	6,735	1	6,735	
2	100	Preparing Right of Way (4%)	LS	8,980	1	8,980	
3	110	Excavation	CY	20	1,028	20,556	Assumed total length of storm sewer pipe
4	164	Seeding for Erosion Control	SY	2	0	0	
5	351	Flexible Pavement Structure Repair (6")	SY	33	0	0	
6	402	Trench Excavation Protection	LF	3	1,850	5,550	Assumed total length of storm sewer pipe
7	462	Reinforced Concrete Pipe 52 Inch	LF	75	300	22,500	Quantities of storm sewer pipe were estimated from Walker, Wiederhold, and Assoc. "Proposed Storm Sewer Schematic" Figure
7	462	Reinforced Concrete Pipe 48 Inch	LF	75	600	45,000	
8	462	Reinforced Concrete Pipe 42 Inch	LF	75	300	22,500	
9	464	Reinforced Concrete Pipe 36 Inch	LF	69	300	20,700	
9	464	Reinforced Concrete Pipe 30 Inch	LF	44	350	15,400	
10	465	Curb Inlet (TY II) (10')	EA	2700	26	70,200	Assume all inlets in increments of 10 ft
	465	Manhole	EA	3000	2	6,000	Assumed
13	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
14	506	Temporary E&S Controls	LS	300	2	600	
12		Engineering and Design Services (8%)	LS	17,960	1	17,960	
					Subtotal	264,200	
					25% Contingency	66,100	
					Total	330,300	

* Based on Walker, Wiederhold, and Associates quantities

Table 9
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	3	4	3	3	0	13	$330,300



Legend

- Drainage Easement
- Stream Centerline
- 2-ft Elevation Contour

0 700 1,400 Feet

N

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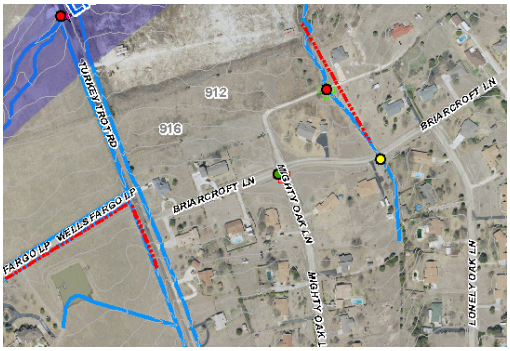
Phone: (512) 327-6840

2012-02 & 2012-03 Woodrow Drive Proposed Storm Sewer

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 700 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-02 2010-03 Woodrow Dr SS Drainage Improvements.mxd	

2008-05 Briarcroft Lane Culvert and Ditch/Channel Improvements



Site Description: This neighborhood was originally identified in the 2008 DMP for the recently annexed areas. Street flooding and some property damage have been recorded in this area, in particular at the intersection of Briarcroft Lane and Mighty Oak Lane and at the drainage outlet on Briarcroft Lane, where at least one resident has reported storm water inside their home. There is a split flow at the intersection of Briarcroft and Mighty Oak Lane and the majority of the flow appears to flow down Briarcroft Lane. However, in order to help relieve high flows at the outlet channel, it is recommended that the drainage be completely directed along Mighty Oak Lane. To accommodate the resulting higher flows on Mighty Oak, the existing ditches will also need to be improved. It would likely be useful to enlarge the outlet channel to convey the 50-year flow. The outfall channel currently only has about a 10-year storm flow capacity. Enlarging the outfall channel would lower the backwater and improve overall conveyance and lessen street flooding. Finally, there are 3 – 30-inch cross culverts at Briarcroft Lane at the upstream end of the outfall channel that are undersized. Three cost estimates[1] (Table 10, 11 and 12) are presented below for improving 1) the Briarcroft/Mighty Oak Split flow, 2) Briarcroft cross culverts, and 3) the earthen outlet channel.

Perceived Benefit: This neighborhood has a fairly well documented history of drainage issues causing both street and residential property flooding. Drainage improvements would be well received.

Summary: This project should be considered a fairly high priority. At a minimum, improvements to the 3 – 30" RCPs and the outlet channel should be considered. This would improve transportation access through the neighborhood and offer reasonable good engineering economy. It should be considered as moderately high priority.

[1] Cost originally estimate from 2008 DMP escalated to 2011 dollar values

Table 10
Reroute Split Flow to Drain Entirely to the North thereby Reducing Flow to Briarcroft Culvert at POC 7
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price ($/unit)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	1,142	1	1,142	Quantities taken from 2008 DMP
2	100	Preparing Right of Way (4%)	LS	1,523	1	1,523	
3	110	Excavation	CY	20	351	7,013	
4	132	Embankment	CY	6	2	13	
5	164	Seeding for Erosion Control	SY	2	117	234	
6	351	Flexible Pavement Structure Repair (6")	SY	33	44	1,467	
7	464	Reinforced Concrete Pipe 36 Inch	LF	69	40	2,760	
8	496	Removing Structures	LF	20	26	520	
9	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
10	506	Temporary E&S Controls	LS	300	3	900	
11		Engineering and Design Services (30%)	LS	4,322	1	4,322	
12	--	Drainage Easement Acquisition	SF	4.5	5,260	23,670	
					Subtotal	45,100	
					25% Contingency	11,300	
					Total	56,400	

Table 11
Increase Briarcroft Culvert Outlet to 50-yr LOS, Improve Surrounding Ditches
Cost Estimate

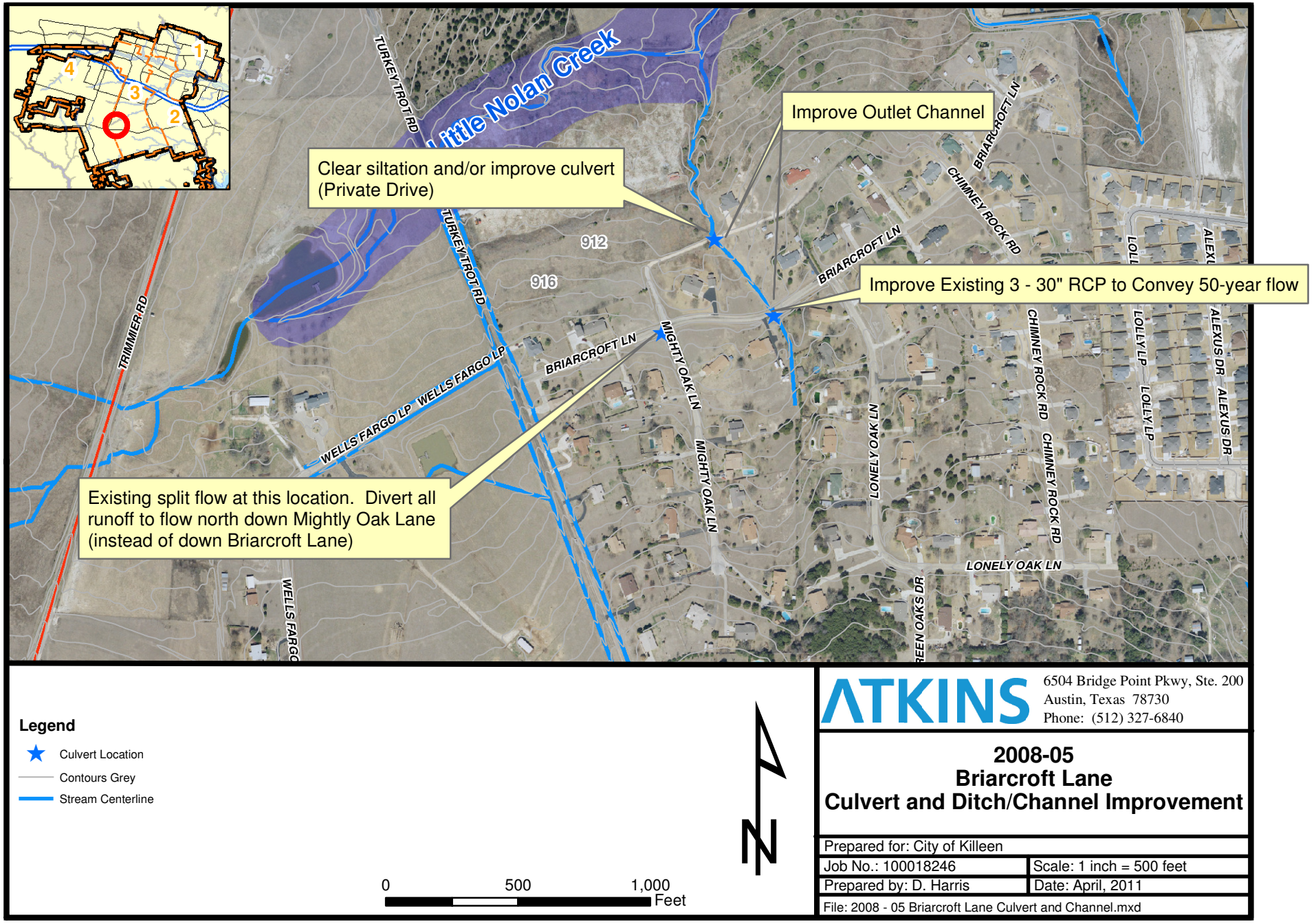
Item No.	TxDOT Spec	Item	Units	Unit Price ($/unit)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	1,179	1	1,179	Quantities taken from 2008 DMP
2	100	Preparing Right of Way (4%)	LS	1,572	1	1,572	
3	110	Excavation	CY	20	370	7,407	
4	132	Embankment	CY	6	15	87	
5	164	Seeding for Erosion Control	SY	2	1,111	2,222	
6	351	Flexible Pavement Structure Repair (6")	SY	33	44	1,467	
7	462	Concrete Box Culverts (1-5'x3')	LF	150	72	10,800	
8	466	Headwalls and Wingwalls	EA	10,000	2	20,000	
9	496	Removing Structures	LF	20	26	520	
10	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
11		Engineering and Design Services (30%)	LS	13,201	1	13,201	
12	506	Temporary E&S Controls	LS	300	1	300	
					Subtotal	60,300	
					25% Contingency	15,100	
					Total	75,400	

Table 12
Improve Tanglewood Estates Neighborhood Outlet Channel
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price ($/unit)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	843	1	843	Quantities taken from 2008 DMP
2	100	Preparing Right of Way (4%)	LS	1,124	1	1,124	
3	110	Excavation	CY	20	389	7,778	
4	132	Embankment	CY	6	2	13	
5	164	Seeding for Erosion Control	SY	2	389	778	
6	351	Flexible Pavement Structure Repair (6")	SY	33	44	1,467	
7	464	Reinforced Concrete Pipe 24 Inch	LF	44	96	4,224	
8	496	Removing Structures	LF	20	26	520	
9	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
10	506	Temporary E&S Controls	LS	300	1	300	
11		Engineering and Design Services (30%)	LS	4,974	1	4,974	
12	--	Drainage Easement Acquisition	SF	5	3,500	15,750	
					Subtotal	39,300	
					25% Contingency	9,800	
					Total	49,100	

Table 13
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	2	3	4	3	0	12	$180,900



Legend

- Culvert Location
- Contours Grey
- Stream Centerline

0 500 1,000 Feet

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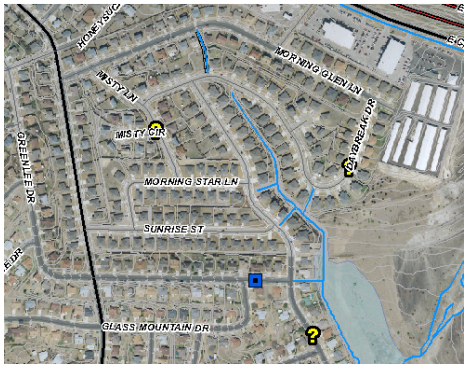
2008-05
Briarcroft Lane
Culvert and Ditch/Channel Improvement

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 500 feet
Prepared by: D. Harris	Date: April, 2011
File: 2008 - 05 Briarcroft Lane Culvert and Channel.mxd	

2012-16 Misty Lane Phase 2 Storm Sewer



Site Description: This project was originally proposed in the 2005 DMP (CIP #14). As a result, a PER was developed by Wallace Group (May 2010). According to the Wallace PER, there are 14 residential complaints related to flooding in this area. In addition, this area is known to have a high ground water table, which also exacerbates drainage issues.

The Wallace Group PER evaluated a proposed storm sewer from Honeysuckle Drive down Morning Star Lane, and channel improvements on Acorn Creek and the Bending Trail Ditch, as well as upsized cross culverts at Acorn Creek Trail to 3 – 6' X 5' RCB culverts. Upsized culverts will help prevent clogging, which is likely the source of past drainage issues on Morning Star Ditch. One home reported flooding during the September 2010 event on Greenlee Drive due to overflowing of the ditch behind the property. This issue arose after the Wallace report was submitted and therefore was not addressed in the report. Given the known drainage issue, the ditch behind Greenlee Drive should be considered for maintenance and possible grading improvements.

Some soil erosion in the overbank was observed here. This erosion is likely to progress into private property and compromise residential fences in the future.

Perceived Benefit: A large quantity of water is conveyed in the streets along Misty Lane, and storm sewer improvements would increase safety and transportation access. Additionally, upsized culverts on Acorn Creek Trail to pass flows from the Misty Lane ditch would help prevent overtopping on Acorn Creek Trail and reduce the risk of clogging that has been known to occur. Finally, the ditch on Greenlee Drive should be maintained and possibly improved to prevent residential drainage issues in this area.

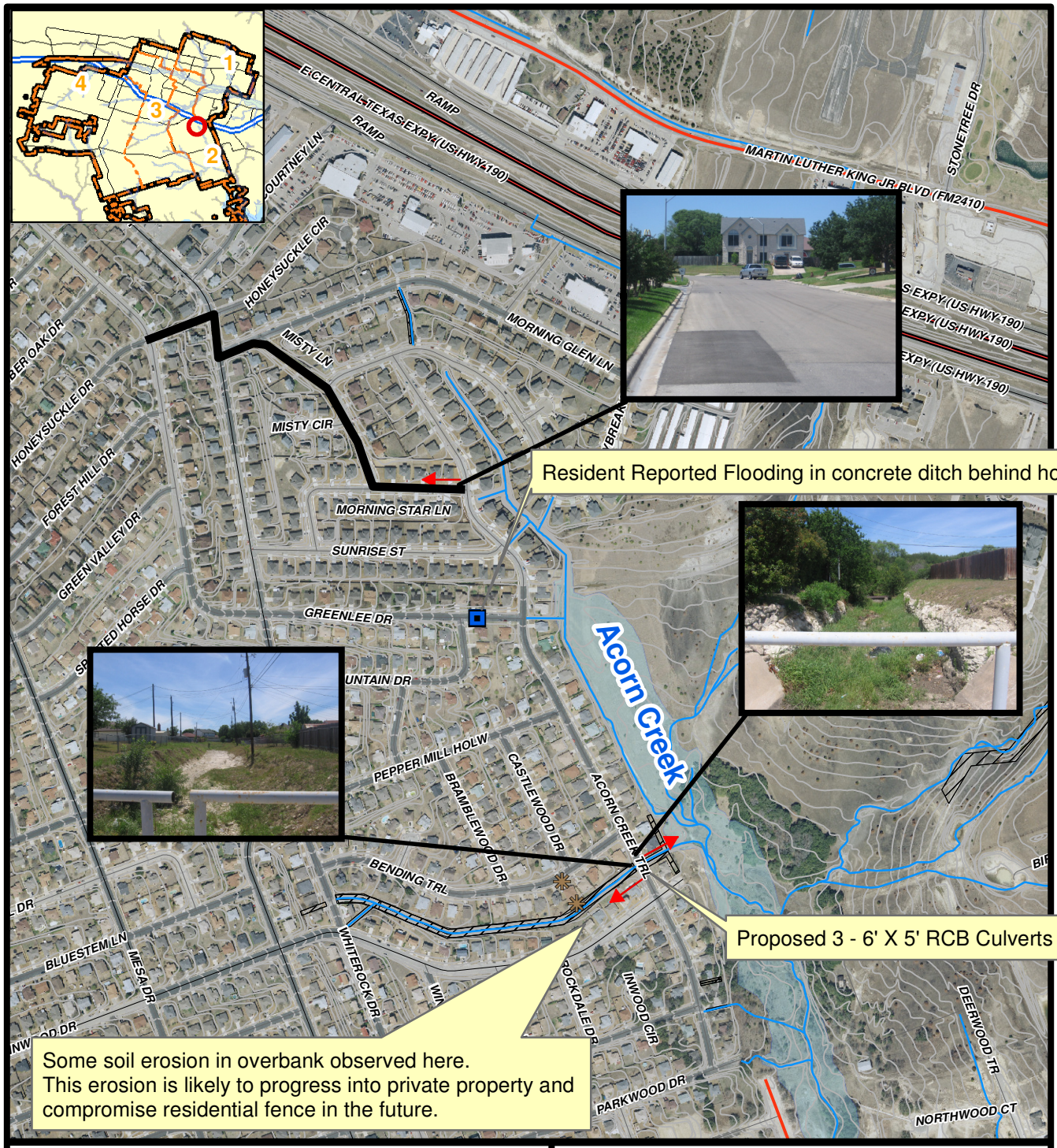
Summary: Only one property reported flooding in the September 2010 event in this area, and that was along Greenlee Drive from a ditch that was not evaluated in the Wallace Group Report. The Greenlee Drive ditch should therefore be considered for maintenance and improvements. Otherwise, no other residential properties reported flooding for the September 2010 event. However, there are known drainage issues, in particular from storm water flowing down Misty Lane and due to clogging at the cross culvert at Acorn Creek Trail and Bending Trail Ditch. Therefore, the project should be considered as a moderately high priority. However, the channel improvements for Acorn Creek and Bending Trail Ditch do not appear to be warranted by the need to alleviate home flooding in this area and therefore are not considered to be a high priority.

Table 19
Wallace Group Cost Estimate

Project Summary From Walker PER Recommendations	Cost
General Conditions, (Mobilization SWPPP)	$69,000
Channel Improvements	$526,900
Closed Conduit Improvements	$820,800
Total with 25% Contingency	**$1,770,875**

Table 20
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	2	2	2	2	0	8	$1,770,875



Legend

- Proposed Storm Sewer
- Direction Photo
- House Flooding
- Erosion

100 Yr FEMA Floodplain

- Zone A
- Zone AE
- Drainage Easement
- Existing 2 ft Contours
- Stream Centerline

0 700 1,400 Feet

N

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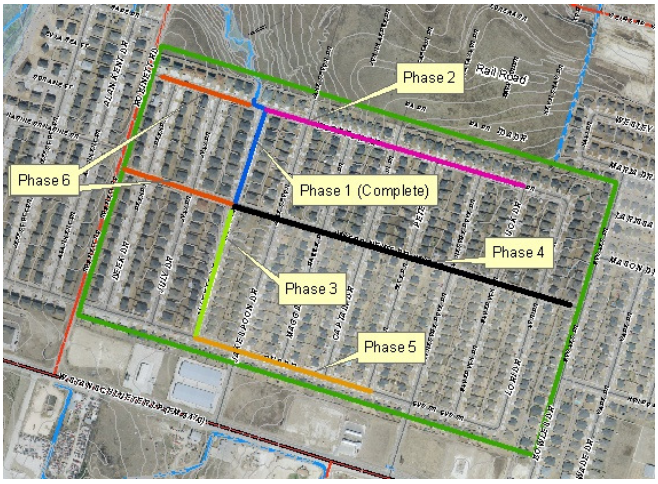
2012-16 Misty Lane Storm Drain

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 200 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-16 Misty Lane Storm Drain.mxd	

2012-03 Woodrow Phase 3 Storm Drain and Inlets



Site Description: As discussed in CIP 2012-02, this neighborhood discharges at Woodrow Drive. The existing infrastructure is insufficient to cope with the runoff that concentrates at the discharge point. Recently, a study was performed by Walker, Wiederhold, and Associates that recommended improving the drainage outlet and additional phases of storm sewer construction. A total of six phases was recommended. The first phase including the outlet and first reach of storm sewer has been constructed. Phase 3 extends the main trunk line leading from the outlet. This storm sewer would provide inlets that would help to drain Alleeta Drive, and it would extend the trunk line of the system farther south into the neighborhood, which would facilitate future lateral storm sewer improvements throughout the rest of the neighborhood.

Perceived Benefit: This area is densely populated, and the improvements would be recognized by the citizens as a useful drainage project.

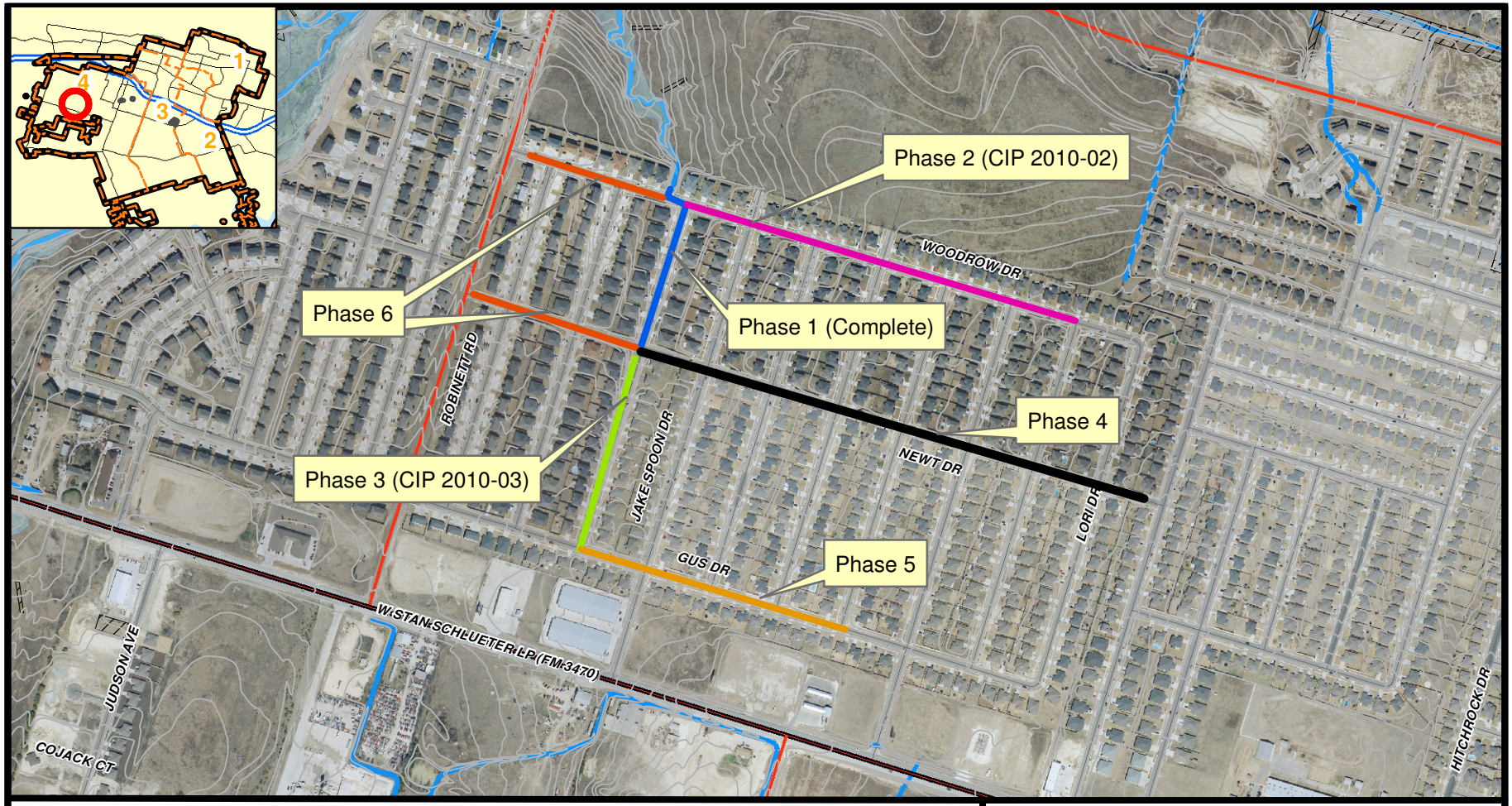
Summary: This project has good engineering economy and will continue to improve transportation access. Phase 3 should be considered to have moderately high priority.

Table 14
Phase 3 Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	2,703	1	2,703	
2	100	Preparing Right of Way (4%)	LS	3,604	1	3,604	
3	110	Excavation	CY	20	500	10,000	Assumed total length of storm sewer pipe
5	351	Flexible Pavement Structure Repair (6")	SY	33	0	0	
6	402	Trench Excavation Protection	LF	3	900	2,700	
7	462	Reinforced Concrete Pipe 48 Inch	LF	75	500	37,500	Quantities of storm sewer pipe were estimated from Walker, Wiederhold, and Assoc. "Proposed Storm Sewer Schematic" Figure
8	462	Reinforced Concrete Pipe 42 Inch	LF	75	400	30,000	
10	465	Curb Inlet (TY II) (10')	EA	2,700	3	8,100	
11	465	Curb Inlet (TY II) (15')	EA	3,600		0	
	465	Manhole	EA	3,000	1		Assumed
12	466	Headwalls and Wingwalls	EA	10,000	0	0	
13	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
14	506	Temporary E&S Controls	LS	300	1	300	
12		Engineering and Design Services (8%)	LS	7,208	1	7,208	
					Subtotal	103,600	
					25% Contingency	25,900	
					Total	129,500	

Table 15
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	3	3	2	3	0	11	$129,500



Legend

- Drainage Easement
- Stream Centerline
- 2-ft Elevation Contour

0 700 1,400 Feet

N

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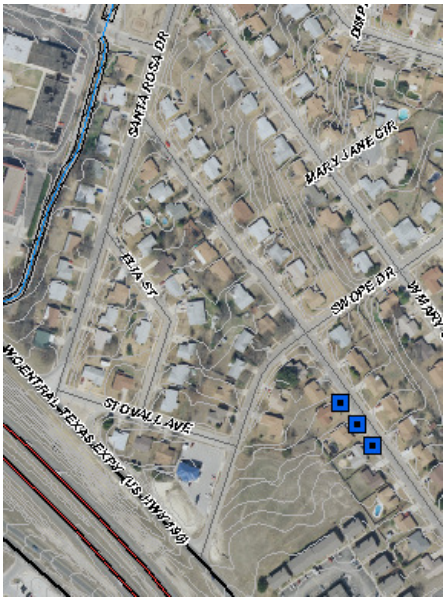
2012-02 & 2012-03 Woodrow Drive Proposed Storm Sewer

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 700 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-02 2010-03 Woodrow Dr SS Drainage Improvements.mxd	

2012-07 Skyline Avenue Storm Drain and Inlets



Site Description: The top of the drainage area where there is an apartment complex is completely impervious. Drainage from the apartment complex (drainage area 1 from Table 16) seems to runoff into a ditch that has formed behind the homes on Skyline Avenue. This ditch is eroding and has insufficient capacity and therefore causes home flooding. Drainage from the apartment complex is also intercepted in a drop inlet and is then conveyed through a storm sewer that outlets onto Swope Drive. The drainage from the apartment should be intercepted before it gets to the eroded ditch or directed to the existing drop inlet.

The drainage enters the drop inlet and storm sewer outfalls at Swope Drive at high velocities and flows quickly down to the corner of Swope Drive and Skyline Avenue where it has a tendency to flow through some residential back yards and generally inundates the street along Skyline Avenue. It is therefore recommended that the drainage from the existing storm sewer outfall be captured in a proposed storm sewer and carried to the open channel outfall, and that storm drain inlets be added to captured flow from Skyline Avenue.

Perceived Benefit: A number of residents have experienced repeated flooding in their homes and yards, and these improvements would alleviate nuisance flooding and improve transportation drainage on Swope Drive and Skyline Avenue as well as help prevent home flooding.

Summary: At a minimum, runoff from the apartment complex should be directed away from the three homes that reported flooding in the September 2010 event, and the water should be directed towards the existing drop inlet. Designs should be developed to prevent flooding in the eroded ditch behind the homes on Skyline Avenue where flooding is known to occur. As funding is available, a storm sewer system should be considered to convey the runoff to the outfall to prevent home and yard flooding along Skyline Avenue.

Table 16
Runoff Estimate (Rational Method)

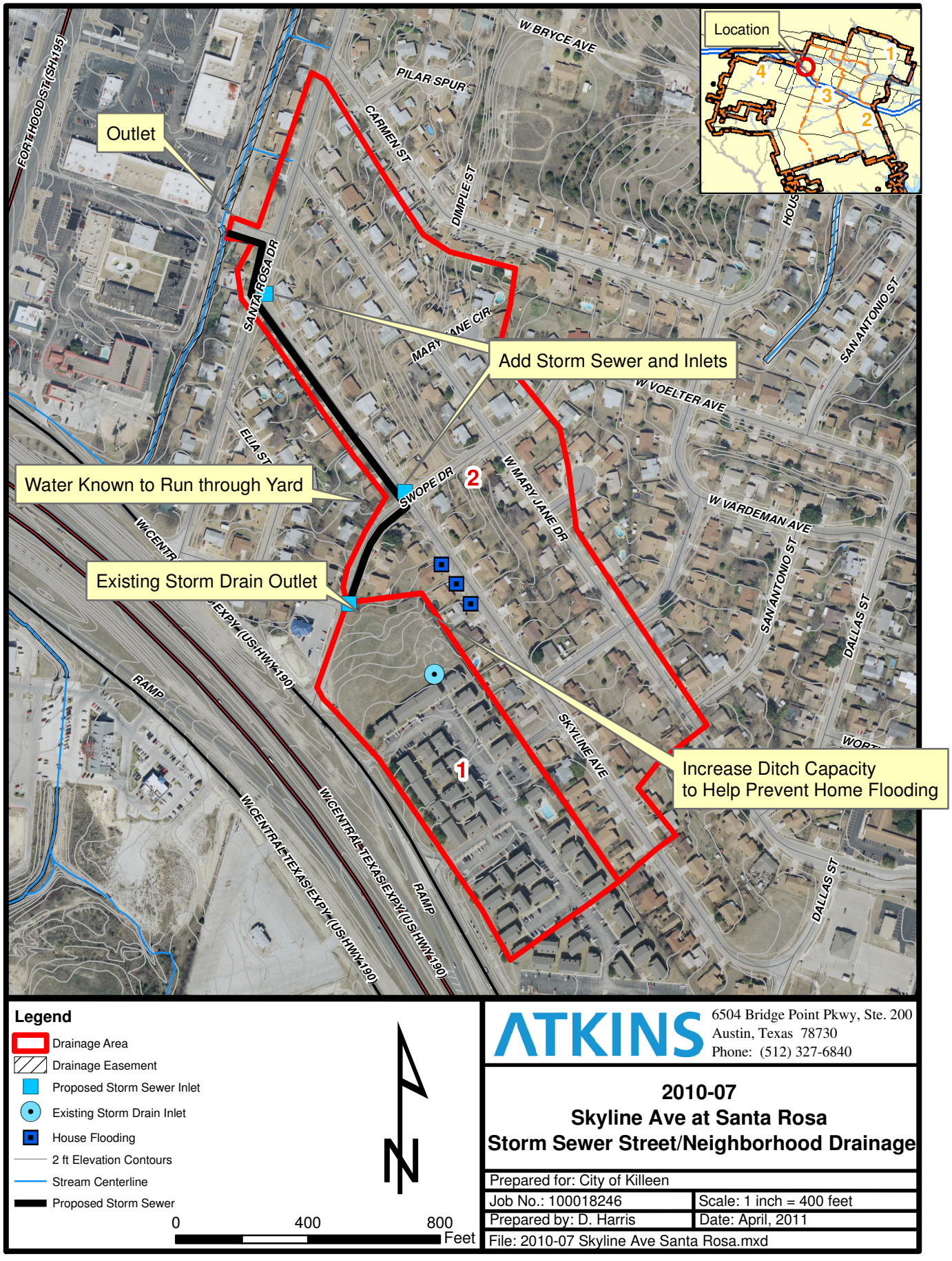
Drainage Area ID	Drainage Area (acres)	2-Yr	10-Yr	25-Yr	50-Yr	100-Yr
		(cfs)				
1	10	28	41	53	62	73
2	29	72	105	136	161	189

Table 17
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit Price ($/unit)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	5,473	1	5,473	
2	100	Preparing Right of Way (4%)	LS	7,298	1	7,298	
3	110	Excavation	CY	20	2,169	43,389	
4	164	Seeding for Erosion Control	SY	2	100	200	
5	351	Flexible Pavement Structure Repair (6")	SY	33	1,302	42,955	
6	402	Trench Excavation Protection	LF	3	2,343	7,029	
7	464	Reinforced Concrete Pipe 36 Inch	LF	69	914	63,066	Assumed pipe diameter
8	464	Reinforced Concrete Pipe 24 Inch	LF	44	500	22,000	Assumed pipe diameter
	485	Curb Inlet (TY II) (15')	EA	3,600	3	10,800	Assumed Inlet opening
10	502	Barricades and Traffic Handling	LS	1,500	1	1,500	
11	506	Temporary E&S Controls	LS	300	1	300	
12	--	Outfall Armoring	EA	2,000	1	2,000	
13	--	Utility Relocation (5%)	LS	0	1	0	
		Engineering and Design Services (10%)	LS	19,324	1	19,324	
					Subtotal	225,300	
					25% Contingency	56,300	
					Total	281,600	

Table 18
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	2	3	4	3	0	12	$281,600



Legend

- Drainage Area
- Drainage Easement
- Proposed Storm Sewer Inlet
- Existing Storm Drain Inlet
- House Flooding
- 2 ft Elevation Contours
- Stream Centerline
- Proposed Storm Sewer

0 400 800 Feet

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2010-07
Skyline Ave at Santa Rosa
Storm Sewer Street/Neighborhood Drainage

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 400 feet
Prepared by: D. Harris	Date: April, 2011
File: 2010-07 Skyline Ave Santa Rosa.mxd	

2005-26 Wolf Ditch Storm Drain

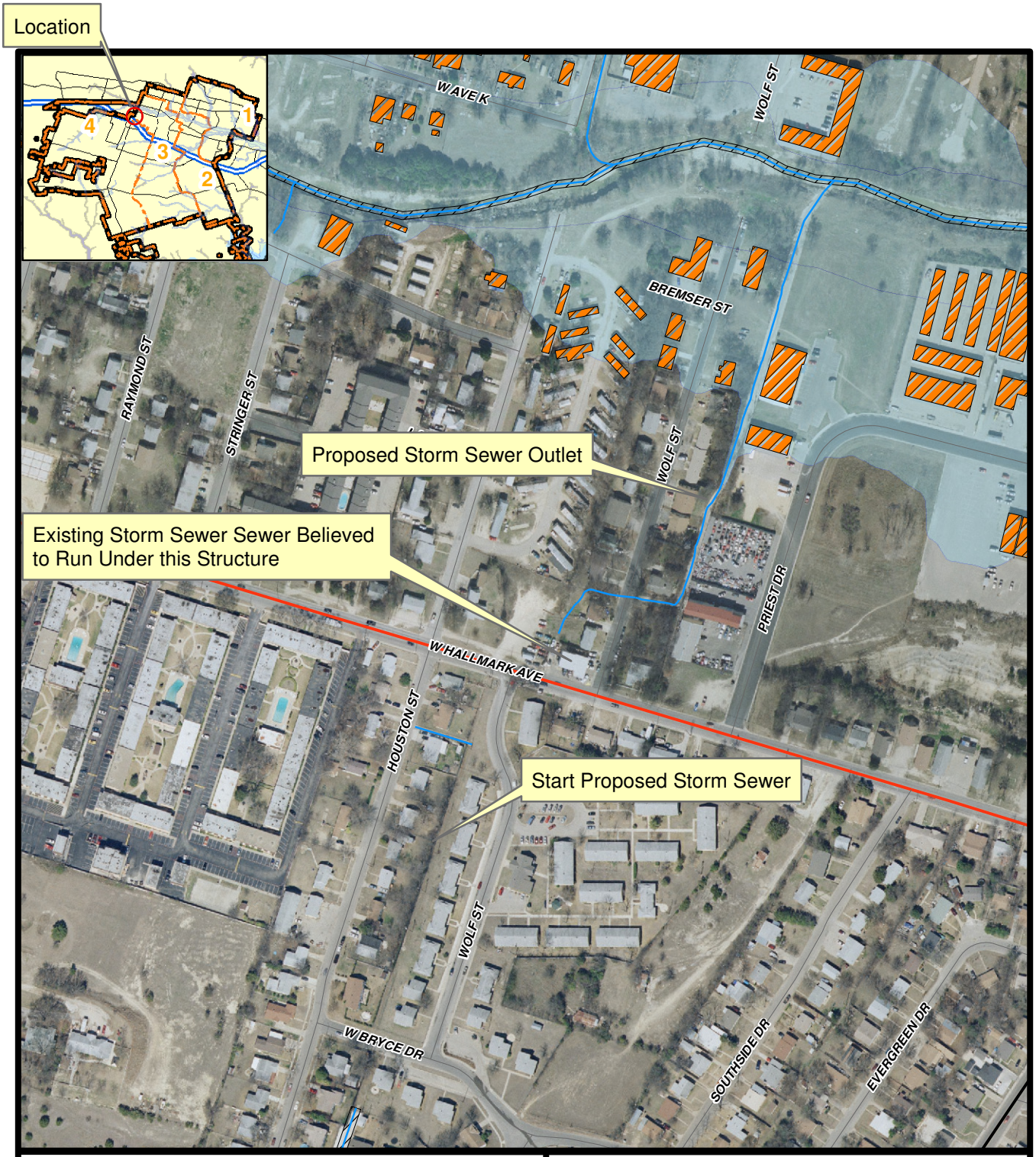
Site Description: This project was identified in the 2005 DMP that recommended a new storm sewer pipe. The existing pipe evidentially runs under existing property and may be undersized. However, there are no major drainage issues known to occur in this location. No home flooding was reported from the September 2010 event.

Perceived Benefit: By replacing and upsizing this pipe, it could be realigned so that it does not run underneath private property and structures. Additionally, increasing the size of the pipe would reduce backwater at the inlet, which may improve residential drainage issues.

Summary: There are no known serious drainage issues in this area, and it is not likely that drainage benefits would outweigh the cost. Therefore, this area is considered to be a low priority capital improvement project.

Table 21
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	1	0	2	1	0	4	$595,991



Legend

- Houses in 100-yr Floodplain
- Zone AE
- Drainage Easement
- Stream Centerline

0 300 600 Feet

N

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2005-26
Wolf Ditch Storm Sewer

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 200 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005-26 Wolf Ditch Storm Sewer.mxd	

Appendix B.3

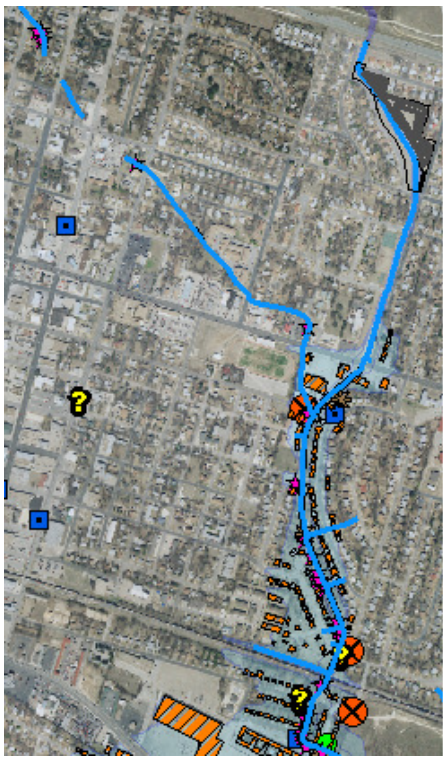
Stream Channel Repair and Floodplain Improvements

Schematic CIP Projects

Stream Repair and Improvements

Schematic Ponds

2012-11 Stewart Ditch Repair



Site Description: Stewart Ditch is a concrete-lined channel with 1:1 side slopes, approximately 3 to 6 ft deep with a 10- to 15-ft bottom (approx.). The headwaters of this stream are within Fort Hood. Stewart Ditch has a capacity of approximately the 10-year storm event. There are more than 25 locations with structural failures identified on Stewart Ditch. At 5 locations, the concrete panels have been completely washed away. There are numerous other locations where concrete panels have formed long and deep cracks, and there are several locations where the soil has started to wash out behind the concrete on the top of bank, thereby threatening to undermine the whole concrete panel.

The Stewart Ditch watershed is highly impervious and generates a considerable flow of 4,317 cfs (Table 2) at the outlet with South Nolan Creek. There are about 88 structures in the Stewart Ditch 100-year FEMA floodplain. There are also a number of structures in the South Nolan Creek floodplain, which creates a significant backwater on Stewart Ditch. Stewart Ditch has a drainage easement approximately 40 ft wide, while the channel top width is about 15 to 25 ft wide. Therefore, there may be some room available for enlarging the existing concrete ditch (although some temporary construction easements might be necessary). To convey the 50-year flow within the channel would require modifying the channel to approximately 25 ft bottom with 1:1 side slopes and approximately 5 ft deep from E. Rancier Avenue (FM 439) downstream to where the South Nolan Creek backwater governs the water surface elevation.

The flooding issues in this reach are significant and detailed assessments of feasibility and cost estimates for alternative channel improvements are beyond the scope of this Drainage Master Plan, and would require a preliminary engineering report for the entire reach of Stewart Ditch to determine. The cost to improve this channel would be considerable, but might be justified given the number of structures in the FEMA 100-year floodplain. Concrete channel repairs alone are estimated to cost approximately $238,300 (Table 1).

Perceived Benefit: Stewart Ditch has perhaps the most severe structural failures of any concrete-lined channel within the City of Killeen. If left unrepaired, further erosion will occur and more concrete panels are likely to be undermined and washed out in future storm events. Additionally, there are numerous structures in the FEMA 100-year floodplain and the channel has inadequate capacity. The channel would therefore benefit from widening if found to be cost effective.

Summary: This is a high priority stream reach for infrastructure repair projects. Significant failures have left the channel highly susceptible to even more failures in subsequent storm events. It is recommended that the concrete panels that have been washed away be replaced and the areas where the top of bank has started to erode behind the concrete be reinforced with rock riprap or a nonbiodegradable geotextile. To completely repair all the concrete failures, major cracks, and overbank washout areas would cost approximately $238,300; however, critical repairs might be done for less. Due to the large number of

structures within the 100-year floodplain, it is recommended that a preliminary engineering study be commissioned to define alternative floodplain improvements and costs.

Table 1
Cost Estimate (Concrete Channel Repair Only)

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	4,630	1	4,630	Assumed
2	100	Preparing Right of Way (4%)	LS	6,173	1	6,173	Assumed
3	132	Embankment	CY	6	1,205	7,110	Rough Approximation
4	164	Seeding for Erosion Control	SY	2	1,000	2,000	Assumed
5	432	Concrete Riprap	CY	300	269	80,556	Rough Approximation
6	432	Stone Riprap (8 IN)	CY	70	312	21,832	Rough Approximation
7	496	Removal of Conc. Riprap	CY	300	128	38,333	Rough Approximation
8	506	Temporary E&S Controls	LS	300	15	4,500	Assumed
11	--	Temporary Construction Easement	SF	2	5,000	10,000	Assumed
12		Engineering Design Services (10%)	LS	15,433	1	15,433	Assumed
					Subtotal	190,600	
					25% Contingency	47,700	
					Total	238,300	

Table 2
Runoff Estimate (HEC-HMS)

Drainage Area (mi^2)	10-Yr	50-Yr	100-Yr
	(cfs)		
1.32	2,312	3,054	3,440
1.72	2,788	3,814	4,317

Table 3
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	4	4	5	2	0	15	862,000

Legend

- Yard Flooding
- Road Closures Only
- House Flooding
- Erosion
- Infrastructure Failures from Sept '10
- 100-Yr FEMA Floodplain Zone AE
- Houses in 100-yr Floodplain
- Stream Centerline

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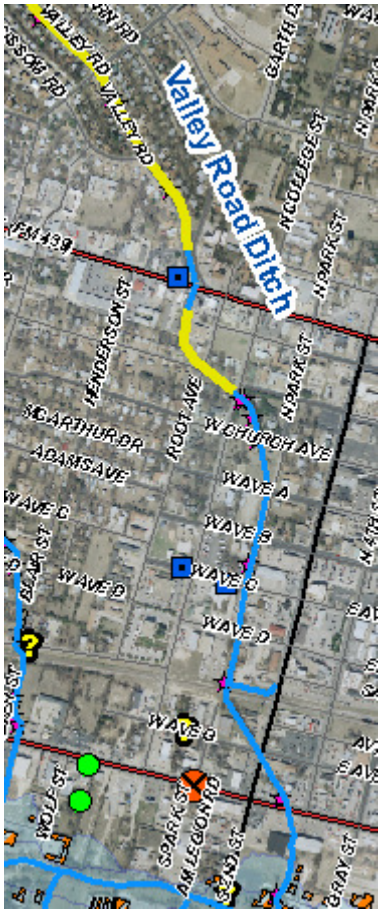
2012-11 Stewart Ditch Repair

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 300 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-11 - Stewart Ditch Repair.mxd	

2005-20 Valley Road Ditch Repair and Floodplain Mitigation



Site Description: Valley Road Ditch has at least 14 distinct locations with drainage infrastructure structural failures. The capacity of Valley Road Ditch varies from the 2-year to the 50-year event. There is not a mapped FEMA floodplain for this ditch. However, this reach was studied by Walker Partners (see Table 2), and existing and proposed 100-year floodplains were generated. From the Valley Road Ditch Study, a number of residential and transportation flooding issues were identified. Preliminary study recommendations included improving channel conveyance by removing one culvert, ditch widening, and improved culverts. The BNSF rail road culvert has already been funded based on this study's recommendation. Walker Partners showed that several residential structures could be taken out of the floodplain with proposed improvements. See Table 4 below for Walker Partners' cost estimate.

As previously mentioned, there are a number of infrastructure failures and maintenance issues in this reach. See Table 2 below for Atkins' cost estimate for the repair of the concrete channel.

Perceived Benefit: There are significant infrastructure failures in need of repair. These failures have the potential to progress and cause more expensive damage in the future, possibly even undermining Valley Road itself (see photographs below) where it runs parallel to the ditch. According to the Walker Partners' study, there are a number of residential structures in the 100-year floodplain; approximately 40 residential structures could be pulled out of the 100-year floodplain.

Summary: The first priority for this reach is to repair the concrete channel; otherwise, the existing failures are likely to progress and create more expensive future failures. The floodplain improvements suggested by Walker Partners has the potential to positively benefit a number of citizens and improve transportation access. The floodplain in this reach should also be mapped and submitted to FEMA to accurately represent flood risks. The total cost from Walker Partners study is $1,299,805 (not including the already funded rail road culvert improvements). Repairing stream failures alone is estimated to cost approximately $324,900.

Table 4
Cost Estimate (Concrete Channel Repair Only)

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	6,689	1	6,689	
2	100	Preparing Right of Way (4%)	LS	8,918	1	8,918	
3	132	Embankment	CY	6	552	3,254	
4	164	Seeding for Erosion Control	SY	2	0	0	
5	432	Concrete Rip Rap	CY	300	370	111,033	
6		Patch Concrete Crack (Epoxy)	LS	500	4	2,000	Assumed price
7	432	Stone Riprap (8 IN)	CY	70	19	1,361	Some rock along banks to prevent erosion
8	466	Headwalls and Wingwalls	EA	10,000	1	10,000	Damaged headwall
9	496	Removal of Conc. Rip Rap	CY	300	279	83,811	
10	506	Temporary E&S Controls	LS	300	5	1,500	
11	--	Drainage Easement Acquisition	SF	4.5			
12	--	Temporary Construction Easement	SF	2	5,000	10,000	
		Engineering and Design Services (10%)	EA	1	21,296	21,296	Assumed price
					Subtotal	259,900	
					25% Contingency	65,000	
					Total	324,900	

Table 5
Walker Partners Cost Estimate

Project Summary From Walker PER Recommendations	Cost
Fairview Drive to Garth Drive: 1. Remove Hillcrest Drive Crossing, and increase channel conveyance	$927,590
Rancier Drive to Root Avenue. Improvements: Install headwall and improved culverts at Root Avenue and increase channel conveyance	$235,965
Avenue A to Avenue B Improvements: Demolish existing concrete channel lining, headwall and improve culvert at Avenue A	$136,250

Table 6
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	3	0	5	3	4	15	1,301,000

Location

Remove Hillcrest Culverts

Valley Road Ditch

Channel Improvements

Improve Conc. Headwalls
Install 2 Additional 5'X4' RCB

Improve Conc. Headwalls
Install 2 Additional 5' X 5' RCB

Funding Approved for
Improvements to Rail Road Culvert

Note: Callouts reflect improvements proposed in Walker Partners Preliminary Engineering Report May, 2010

Legend

- Infrastructure Failures from Sept '10
- Houses in 100-yr FEMA Floodplain
- Yard Flooding
- House Flooding
- Erosion
- Road Closures Only
- 100 Year FEMA Floodplain Zone AE
- Channel Improvements
- Stream Centerline

0 500 1,000 Feet

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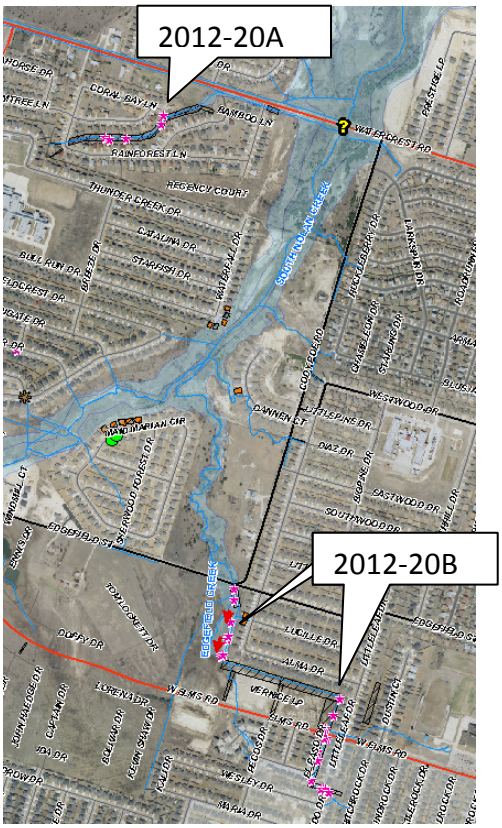
Phone: (512) 327-6840

2005-20
Valley Road Ditch Repair

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 500 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005-20 Valley Road Ditch	

2012-20 Edgefield/Rainforest Dr

2012-20 A Rainforest Drainage Channel



Site Description: The channel banks are highly eroded w channel is approximately 2 to 4 ft deep and about 15 to 30 ft from b the amount of erosion on the banks. The channel invert slopes at abc steep. As a result, there are relatively high velocities and shear stress severe bank erosion. Additionally, there are thick cattails and other v of the channel, which, although reducing the capacity of the ditch prevent erosion in the channel bottom. In any case, the banks are qui

This channel reach should be considered for stream rest restore the channel to a stable condition where water can efficien without causing erosion. It is recommended that the vegetation be back to a stable side slope between 2.5:1 and 4:1 (horizontal:vertica soil stability analysis. The stream bottom should also be stabilized us grade-control structures placed along the channel to maintain a sta lower shear stress to a manageable level that the stream can ha channel bed and banks. The drainage easement is approximately 6 and is probably adequate for any stream restoration activit construction access easements might be required.

Perceived Benefit: This project would stop the loss of the stre the resulting sediment discharge as well as prevent the loss of additic (back yards). Additionally, stream restoration would enhance the aes reach and prevent the loss of residential land area.

Summary: This reach will continue to erode without bed and banks stabilization measures. At a minimum, the channel banks should be laid back to a stable side slope with appropriate vegetation established. With available funding, further stable channel design options should be considered such as rock grade-control structures to prevent further channel downcutting.

Table 7
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	3	3	4	10	150,000

Table 8
2012-20 #1 Rainforest Drainage Channel Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	1,924	1	1,924	
2	100	Preparing Right of Way (Clear Vegetation) (8%)	LS	5,130	1	5,130	Clear cattails and other vegetation
3	110	Excavation	CY	20	396	7,920	
4	132	Embankment	CY	6	396	2,336	
5	164	Seeding for Erosion Control	SY	2	1,484	2,968	
12	432	Stone Riprap (24 IN)	CY	70	360	25,200	5 Grade Control Structures
13	110	Excavation for Stone Riprap Grade Control	CY	20	360	7,200	
31	506	Temporary E&S Controls	LS	300	15	4,500	
34	--	Temporary Construction Easement	SF	2	4,500	9,000	
35	--	Outfall	EA	5,000	1	5,000	
36	--	Utility Relocation (5%)	LS	1	3,206	3,206	

2012-20 B Edgefield Drainage Channel

Site Description: This stream reach is one of the most extreme examples of channel erosion in the City. The soils appear to be silt or clay. Very little vegetation grows within the channel banks in this area. Additionally, the channel slopes at approximately 2% for the top half of this reach. This is steep enough to generate significant shear stresses through the reach. The remains of 2 concrete grade-control drop structures were observed in the field. However, these grade-control structures have been washed out and no longer serve a useful purpose. They should be removed and reconstructed with rock riprap grade controls. There is a concrete-lined 90-degree bend that has significant erosion just downstream of where the concrete ends. Therefore, it is recommended that rock riprap be placed from the edge of the concrete apron downstream for approximately 10 to 15 ft as water transitions from the concrete to the natural soils. The acquisition of some drainage easement may be necessary to perform this work. If required, drainage easement acquisition might represent the majority of the cost for this project.

Perceived Benefit: Stream restoration measures would prevent this stream from eroding further and would add aesthetic value. Furthermore, stream restoration would reduce sediment discharge.

Summary: This stream is highly eroded. If it is not stabilized, it will continue to erode. In its current state, this area has little aesthetic appeal, and stream restoration including replacing the original washed-out concrete and constructing grade controls with rock riprap should be considered. Some drainage easement acquisition may be required.

Table 9
2012-20 #3 Edgefield Ditch

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	1,460	1	1,460	
2	100	Preparing Right of Way (4%)	LS	1,946	1	1,946	
3	110	Excavation	CY	20	321	6,427	Assume equal to embankment
4		Excavation	CY	20	50	1,000	Excavation for rock riprap apron DS of concrete 90-degree bend. Assume 30-*15-*3'
5	132	Embankment	CY	6	321	1,896	Assume exqual to excavation
6	164	Seeding for Erosion Control	SY	2	1,935	3,869	
7	432	Stone Riprap (24 IN)	CY	70	144	10,080	2 grade-control structures
8	432	Stone Riprap (24 IN)	CY	70	50		Rock riprap Apron DS of concrete 90-degree bend. Assume 30-*15-*3'
9	110	Excavation for Stone Riprap Grade Control	CY	20	144	2,880	Assume excavation = rock volume
10	496	Removal of Conc. Riprap	CY	300	20	6,081	Remove existing drop structure (Assume 25' X 10' X 3')
11	506	Temporary E&S Controls	LS	300	15	4,500	
12	--	Drainage Easement Acquisition	SF	5	17,500	78,750	Assume = 35 X 500, ft^2
13	--	Temporary Construction Easement	SF	2	4,500	9,000	
14	--	Outfall	EA	5,000	2	10,000	
15	--	Utility Relocation (5%)	LS	1	2,433	2,433	

Table 10
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	3	2	4	9	250,000

Location

Remove Hillcrest Culverts

Valley Road Ditch

Channel Improvements

Improve Conc. Headwalls
Install 2 Additional 5'X4' RCB

Improve Conc. Headwalls
Install 2 Additional 5' X 5' RCB

Funding Approved for
Improvements to Rail Road Culvert

Note: Callouts reflect improvements proposed in Walker Partners Preliminary Engineering Report May, 2010

Legend

- Infrastructure Failures from Sept '10
- Houses in 100-yr FEMA Floodplain
- Yard Flooding
- House Flooding
- Erosion
- Road Closures Only
- 100 Year FEMA Floodplain Zone AE
- Channel Improvements
- Stream Centerline

0 500 1,000 Feet

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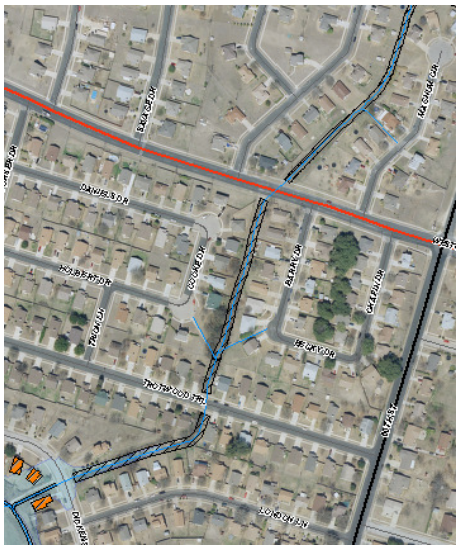
2005-20
Valley Road Ditch Repair

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 500 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005-20 Valley Road Ditch	

2005-24 Dickens Ditch



Site Description: This site was identified in the 2005 DMP for channel clearing and excavation. At the time of the site visit, the channel did not appear to require maintenance, although the stretch of stream between Westcliff Road and Trotwood Trail did have highly eroded banks encroaching somewhat on private property boundaries. Some channel bank armoring and stream restoration may be warranted in this reach. The drainage easement is about 25 ft wide, and the channel appears to be eroding, or is beginning to erode, outside of boundary of the drainage easement. No FEMA floodplain is mapped along this reach. Although there is no record of residential flooding from the September 2010 event, floodplain mapping along this reach should be considered as funding permits.

Perceived Benefit: Stream channel stabilization would prevent the loss of private property (land) and fences and prevent future erosion and sediment discharge.

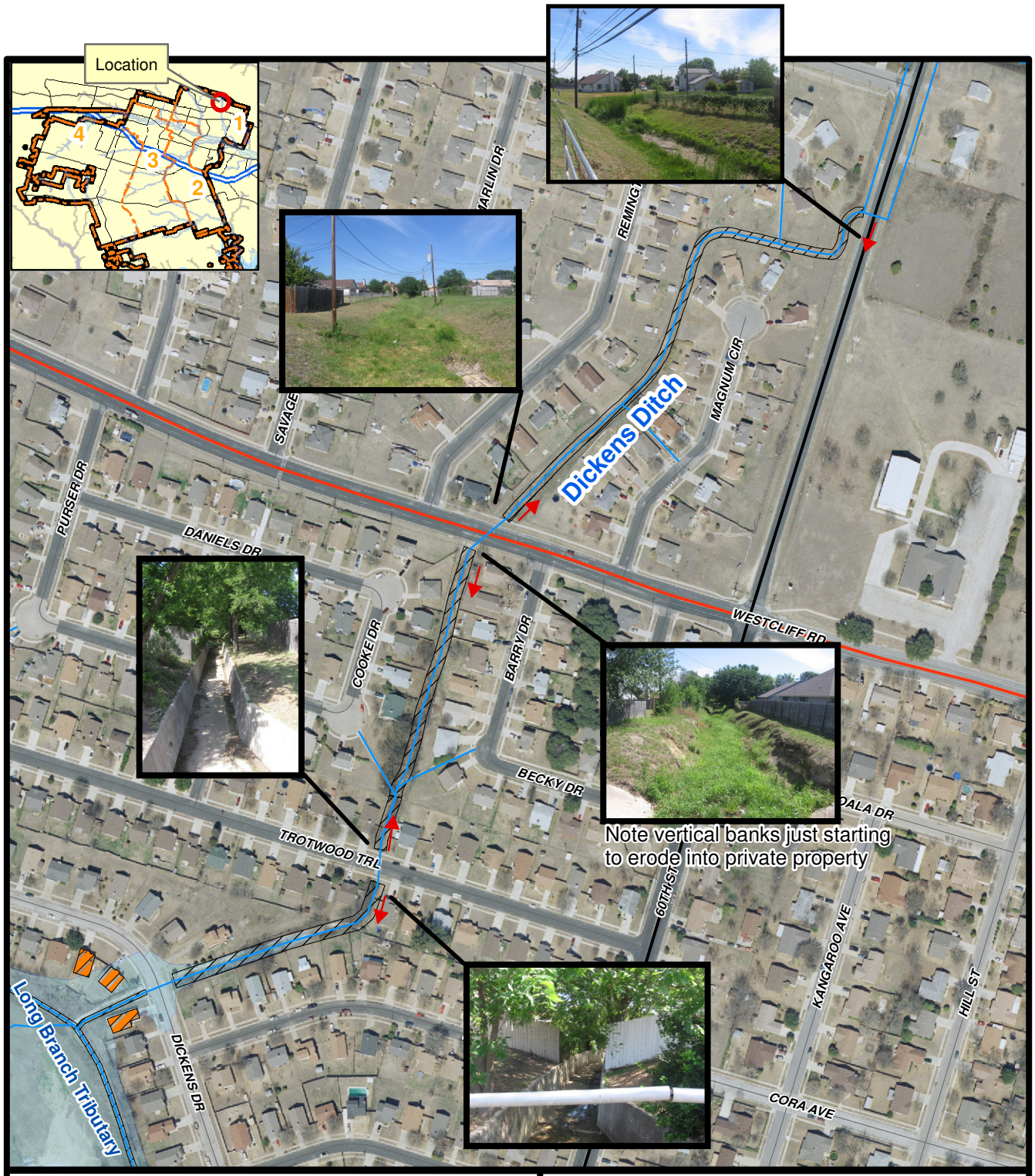
Summary: The reach downstream of Westcliff Road is experiencing some erosion and has the potential to damage private property; this reach also erodes outside of the drainage easement. It is not clear exactly how fast this erosion is progressing toward or outside of the drainage easement, but it is certain to progress with time. Therefore, stream restoration is only considered to be a moderately high priority to prevent erosion before it threatens private land and fences.

Table 11
Cost Estimate From '05 Inflation

Year	Index Value	Cost
2005	288	$291,480
2011	346	$350,181

Table 12
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	4	3	3	10	350,181



Legend

- 100-Year FEMA Floodplain
- Drainage Easement
- Houses in 100-yr Floodplain
- Stream Centerline
- Direction of Photo

N

0 300 600 Feet

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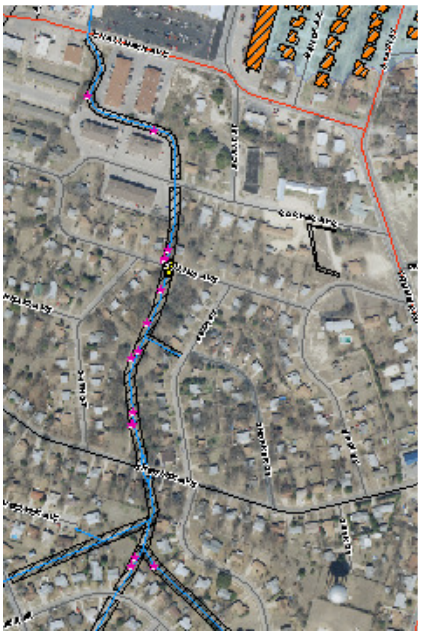
2005-24
Dickens Ditch
Stream Clearing

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 300 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005-24 Dickens Ditch Channel Clearing.mxd	

2012-18 Fowler Run Ditch Infrastructure Repair



Site Description: Fowler Run Ditch is a concrete-lined ditch with approximately 8-ft bottom width, 20-ft top width, 3 to 5 ft deep, and 1 to 1 side slopes. The invert slope is approximately 0.01 ft/ft. The ditch drains a total of 0.43 mi² of highly impervious urban area (Table 7). No FEMA floodplain has been mapped for this channel. The capacity of the ditch appears to be less than the 10-year storm. The channel is within a defined drainage easement approximately 40 ft wide.

There are 16 infrastructure failures identified along the Fowler Run Ditch. The failures include damage to the concrete walls where the concrete wall has failed from the toe of the wall and slipped down, or concrete has failed at the top of the wall where soil has been washed out on the overbank where the concrete wall meets the soil. Repairs would entail replacing whole panels of concrete, patching concrete, and filling in spots that have washed out behind the concrete panels, and possibly adding rock armor on the overbanks to prevent soils from washing out behind the concrete. Given the low capacity of this channel, there are likely a number of residential properties that are in the 1% annual chance floodplain, and floodplain study of this area would be necessary to determine whether ditch capacity improvements are warranted.

Perceived Benefit: Without repairs to this channel, future severe storm events will likely cause significant structural damage at locations where soil has started to wash out behind the concrete wall. There is the possibility of whole concrete panels failing and being washed downstream causing significant soil loss and reduced conveyance. Therefore, repairs to Fowler Run Ditch will prevent further structural damage, prevent erosion, and preserve channel conveyance.

Summary: At a minimum, this channel should be maintained, concrete panels with structural failures should be removed and replaced, and overbank washouts should be filled in and possibly armored with rock to prevent future washouts. A preliminary engineering report identifying the ditch capacity and flooding risks should be considered for this ditch for possible FEMA floodplain mapping and/or ditch improvements. There appears to be enough drainage easement to allow for ditch widening if called for.

Table 13
Runoff Estimate (HEC-HMS)

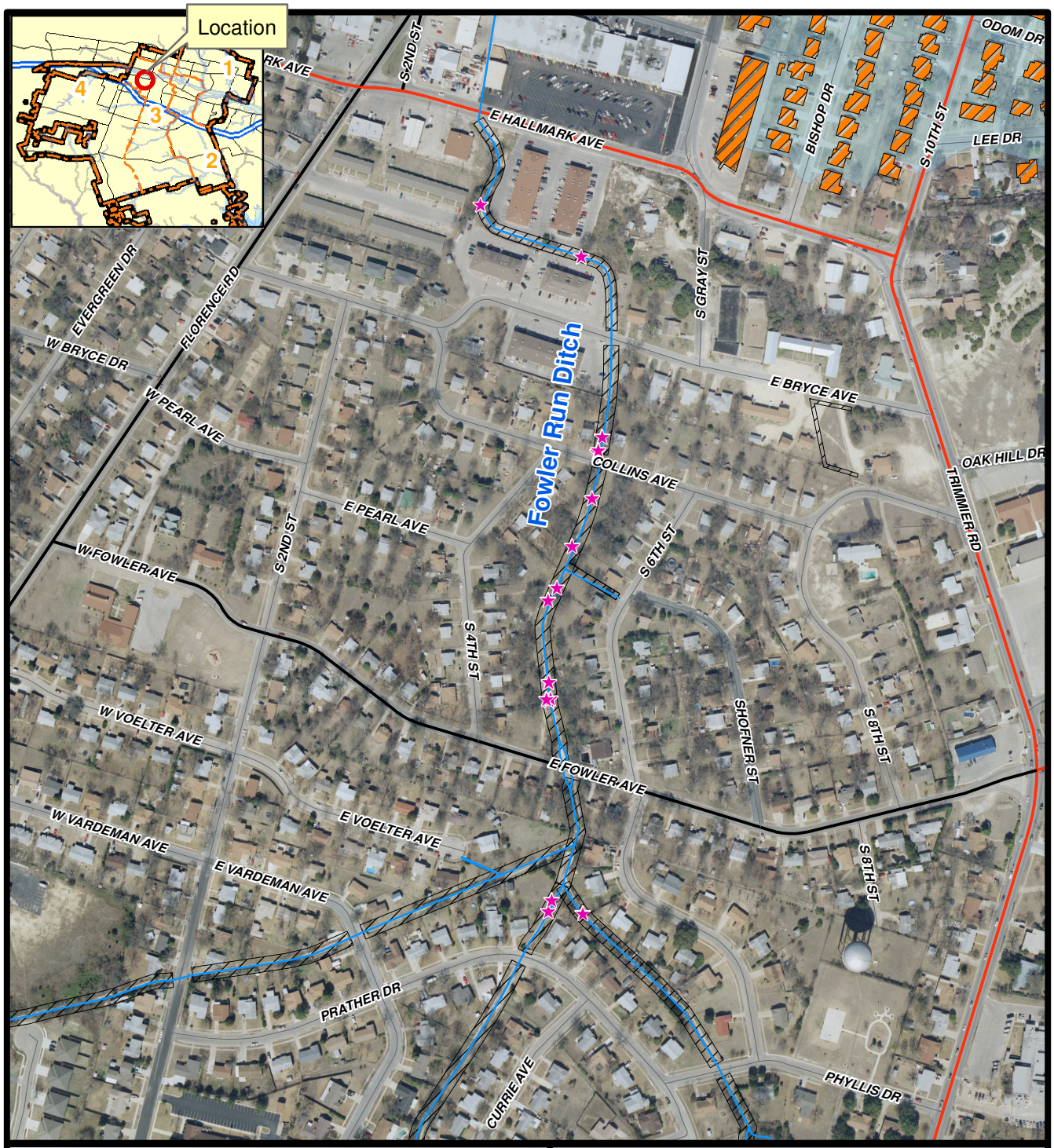
Drainage Area (mi^2)	10-Yr	50-Yr	100-Yr
	(cfs)		
0.26	707	982	1,118
0.43 mi^2 (Outlet)	1,103	1,531	1,751

Table 14
Cost Estimate

Item No.	TxDOT Spec	Item	Units	Unit /Price ($)	Quantity	Item Total	Comment
1	500	Mobilization (3%)	LS	1,954	1	1,954	
2	100	Preparing Right of Way (4%)	LS	2,606	1	2,606	
3	164	Seeding for Erosion Control	SY	2	200	400	
4		Patch Concrete Crack (Epoxy)	LS	500	7	3,500	
5	432	Stone Riprap (12 IN)	CY	70	86	6,028	
6	432	Concrete Riprap	CY	300	108	32,472	
7	496	Removal of Conc. Riprap	CY	300	92	27,472	
8	506	Temporary E&S Controls	LS	300	16	4,800	
9		Engineering and Design Services (10%)	LS	1	7,467	7,467	Assumed price, may not be required for repair
					Subtotal	79,200	
					25% Contingency	19,800	
					Total	99,000	

Table 15
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	5	4	2	11	99,000



Legend

- Infrastructure Failures from Sept '10
- 100-Yr FEMA Floodplain Zone Ae
- Drainage Easement
- Houses in 100-yr Floodplain
- Stream Centerline

N

0 400 800 Feet

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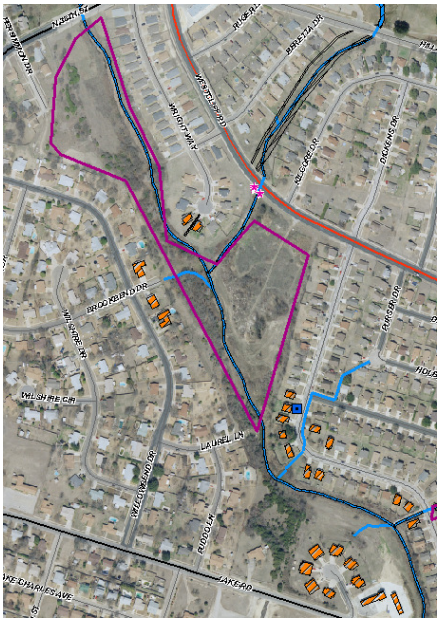
2012-18 Fowler Run Ditch Infrastructure Repair

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 400 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-18 Fowler Run Ditch Infrastructure Repair.mxd	

2005-28 Long Branch Detention and Riffle Pool



Description: This area was originally identified in the 2005 DMP for possible detention. There are about 25 structures in the 100-year FEMA floodplain downstream of this area. Additionally, a number of homes were flooded in the September 2010 event. There is no drainage easement in this area.

The City is currently in negotiations with the landowner to take over the parcel of land running along this reach. Long Branch Creek is a relatively nice stream reach that has not been significantly modified from its original course or channelized due to development activities. A greenbelt runs down this stream and provides some wildlife and aquatic habitat. For instance, beaver dams have been identified in this reach. Although beaver dams can cause flooding issues, they do provide some water quality benefit in small rainfall events, and beaver dams provide habitat for aquatic species. Therefore, it may make more sense to use this area for hike and bike usage and for environmental purposes employing a riffle pool system and possibly constructing water quality ponds to help aerate and in general add aesthetic value to the area.

Perceived Benefit: Constructing a flood control pond as suggested in the 2005 DMP would reduce flows; however, it would require that the existing greenbelt along the stream reach be destroyed. It is not clear whether construction cost for a detention pond would be justified by the benefit. However, a hike and bike system along with a riffle pools system and other environmental and water quality enhancements would benefit the City in general and the neighborhood specifically in terms of water quality and quality of life improvements.

Summary: It is not recommended that this area be used for flood control detention. Rather, it is recommended that this area be considered for hike and bike trails and water quality enhancements using riffle pools and water quality ponds. There are no drainage easements through this reach. Therefore, easement acquisition will likely be the largest driver of cost. A study of alternative water quality and flood control projects specifically for Long Branch Creek should be undertaken to determine the feasibility of water quality improvements within this reach.

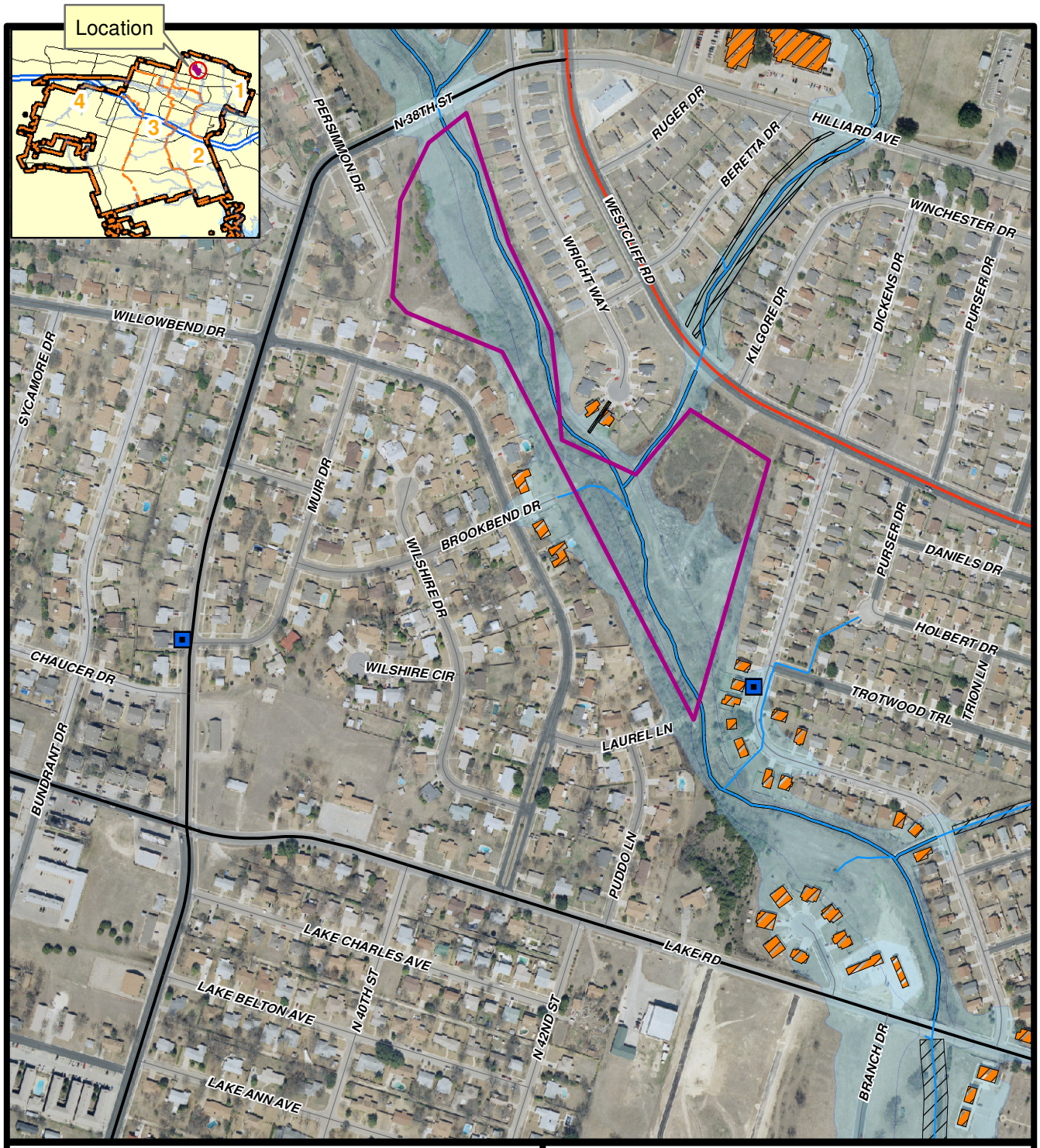
Table 16
Cost Estimate for Detention

Year	Index Value*	Cost**
2005	7563	$225,190
2011	9011	$268,305

* ENR Construction Cost Index
** 2005 cost estimate taken from 2005 Drainage Master Plan and ***do not represent accurate cost for the hike and bike enhancements***.

Table 17
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
Med	0	0	0	0	4	4	500,000



Legend

- FEMA 100-yr Floodplain Zone AE
- Drainage Easement
- Houses in 100-yr Floodplain
- Proposed Detention (Approx. Boundary)
- Stream Centerline
- House Flooding

0 500 1,000 Feet

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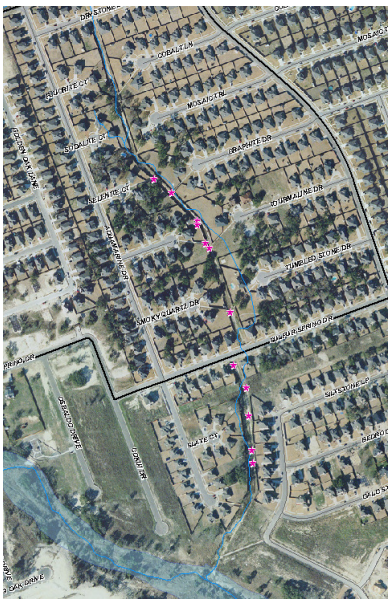
2005 - 28
Long Branch Detention

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 500 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005-28 Long Branch Detention.mxd	

Figure



2012-24 Garcia Ditch Stream Stabilization

Site Description: There are 12 infrastructure failure locations documented along this earthen channel, with "nick points" in the channel bed and eroding banks. This reach is an earthen channel with 1:1 side slopes. Garcia Ditch has experienced rapid erosion due to the steep constructed side slopes and the lack of vegetation in the stream channel and overbanks that is necessary to stabilize channel bed/banks soils against erosion. This reach is eroding rapidly and will likely continue to erode into the banks, threatening fences and residential land. It is likely that the rate of erosion could be reduced if the banks were laid back to perhaps 1.5:1 (H:V). Additionally, it would be advisable to establish vegetation within this reach to the extent practicable. However, the ability of the in situ soils to support vegetative cover should be investigated.

Drainage easement was not documented in the City's drainage easement shapefile. However, that may be due to the relatively recent platting of this area. It therefore is not clear if drainage easement exists for this stream reach.

Perceived Benefit: Channel stabilization measures would prevent the banks from eroding across fence lines and prevent soil sediment discharge. Stabilization through vegetation would also enhance the aesthetic value of the channel.

Summary: This channel has some severely eroded "nick points" within the channel, and the banks are eroding toward residential land, undermining fences and land. This reach should be considered as a moderate priority for stream stabilization measures. The availability of drainage easement is unclear, but is likely available through this reach.

Table 18
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	3	2	3	8	TBD

Legend

- Direction of Photo
- Infrastructure Failures from Sept '10
- Stream Centerline
- Drainage Easement
- 100 Yr FEMA Floodplain Zone AE

0 500 1,000 Feet

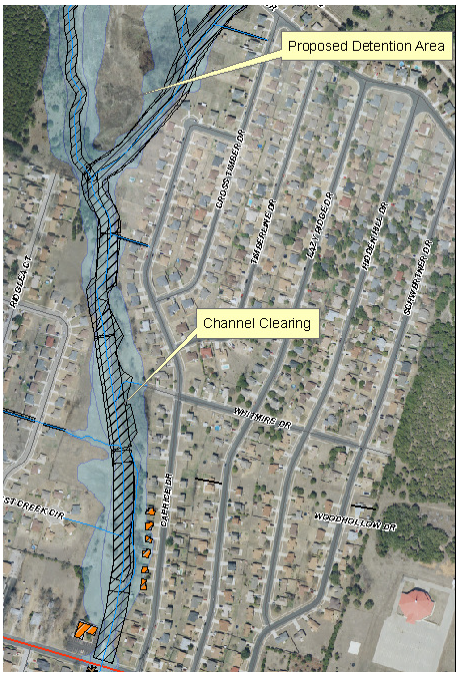
N

ATKINS
6504 Bridge Point Pkwy, Ste. 200
Austin, Texas 78730
Phone: (512) 327-6840

2012-24
Garcia Ditch
Stream Stabilization

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 200 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-19 Cunningham Ditch Repair.mxd	

2005-25 Caprice Ditch



Site Description: This site was identified in the 2005 DMP for channel clearing and potential detention where the two stream branches come together, combining for about 0.095 mi^2 in drainage area. This site is also a candidate for parks and recreation improvements. The proposed detention site is just downstream of Fort Hood, and the amount of future development is not known. However, it is likely that Fort Hood will construct onsite detention for any major construction activities, so it is not clear how much additional runoff capacity exists for this reach in ultimate build-out conditions. Caprice Ditch has been cleared where indicated in the 2005 DMP, and immediate maintenance needs are not currently required for this channel. However, there is one spot where erosion has been reported just downstream of Westcliff Road.

The detention location proposed in 2005 appears viable and may be worth considering to help lessen downstream flooding. There are 20 structures in the 100-year floodplain downstream of this site. Downstream of these structures is a reservoir maintained by the Bell County Water Control & Irrigation District controlling about 1.8 mi^2 of drainage area (Table 17). (The embankment is situated about 1.3 miles upstream of South Nolan Creek.) The Bell County WCID reservoir significantly lowers the downstream flows.

It is unclear whether it would be more cost effective to improve Caprice Ditch in the areas where flooding is predicted to occur or to employ regional detention at the headwaters. A preliminary engineering report would be required to fully define the feasibility of regional detention in Caprice Ditch.

Perceived Benefit: There are enough structures in the 100-year FEMA floodplain downstream of the proposed pond location to make this site feasible for regional detention.

Summary: Given the expense of regional detention, it is likely that the benefits of detention would not outweigh the cost of constructing regional detention.

Table 19
HEC-HMS Flow Summary

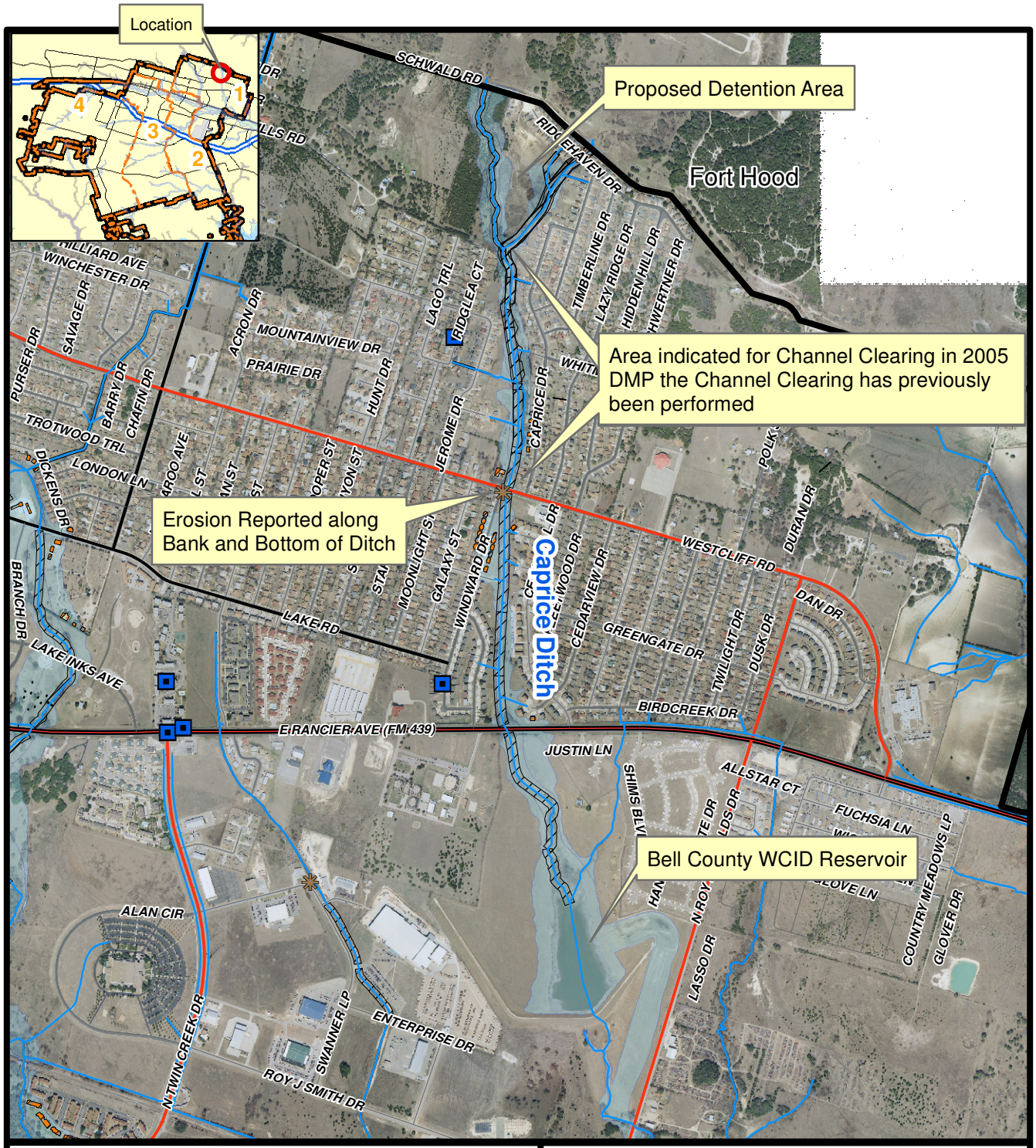
Location	Profile	Drainage Area (mi2)	Peak Discharge (cfs)	Volume (acre-ft)
At Confluence of Fork	50-Year	0.951	*1,856*	298
	100-Year		*2,171*	350
At Bell Co. WCID Reservoir (Discharge)	50-Year	1.823	*48*	231
	100-Year		*48*	236

Table 20
Cost Estimate From '05 Inflation

Year	Index Value	Cost
2005	288	$314,930
2011	346	$378,353

Table 21
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	5	0	1	6	378,353



Legend

- Killeen City Limits
- Houses in 100-yr Floodplain
- Drainage Easement
- Zone AE
- Stream Centerline
- House Flooding
- Erosion

0 1,500 3,000 Feet

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2005-25
Caprice Ditch
Detention and Stream Maintenance

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 1,500 feet
Prepared by: D. Harris	Date: May, 2011
File: 2005-25 Caprice Ditch Detention and Channel Maintenance.mxd	

2005-13 Bending Trail Creek

Site Description: 2005 CIP #13 and 14 (Bending Trail and Acorn Creek) were combined and evaluated in a preliminary engineering report by Wallace Group. The Wallace Group PER considered storm sewer, channel, and culvert improvements in this neighborhood. See discussion given for CIP 2012-16 in the storm sewer and ditch neighborhood drainage section for more detailed information. This ditch has required some maintenance, and the culvert at Acorn Creek Trail is known to have clogged in the past and was therefore proposed for improvement to a 3 – 6' X 5' RCB. Additionally, there are some moderate to low priority erosion issues in the banks. The channel bed is limestone, and therefore only the banks with soil and vegetation are prone to erosion.

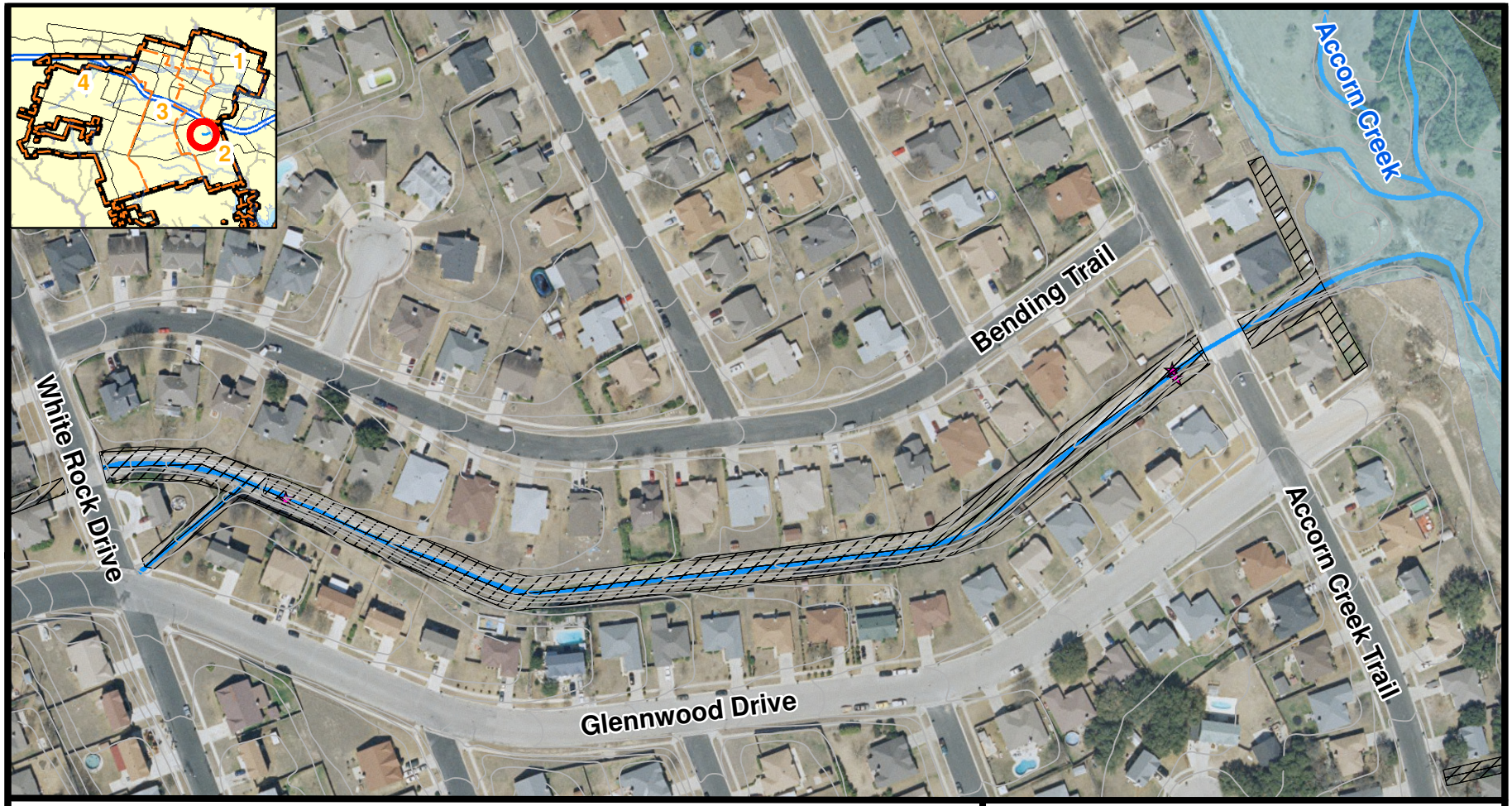
Perceived Benefit: The most distinct benefit to improving this area would be provided by improving the culvert at Acorn Creek Trail, which would help prevent debris clogging and potential future overtopping.

Summary: There is not enough documentation of property damage in this area to justify improvement costs, as opposed to simply needing maintenance. Therefore, this improvement is considered a low priority. This project is prioritized as part of CIP 2012-16 and is not specifically ranked here, but in general is considered a relatively low priority.

Looking upstream at Bending Trail Ditch standing on Acorn Creek Trail cross culvert.

Table 20
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
High	See CIP 2010-16 for additional information and ranking						



Legend

- Infrastructure Failures from Sept '10
- 2 ft Elevation Contours
- Stream Centerline
- Drainage Easement

0 200 400 Feet

N

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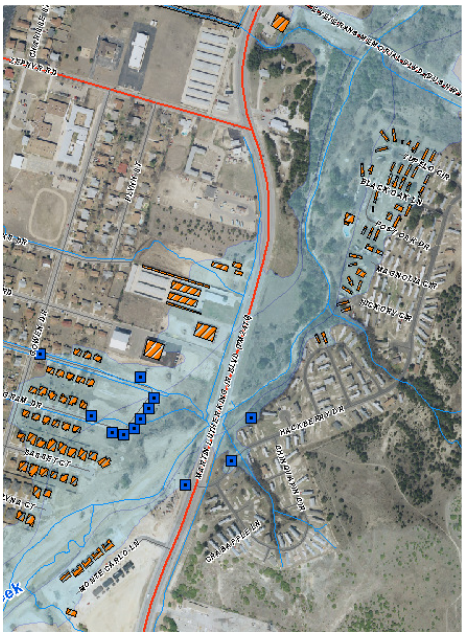
2005-13
Bending Trail Creek
Stream Restoration

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 700 feet
Prepared by: D. Harris	Date: March, 2011
File: 2005 - 13 Bending Trail Creek.mxd	

2012-14 Little Nolan Creek at Pilgrim Drive



Site Description: This general area was identified in the 2005 Drainage Master Plan for capital improvement as CIP #22. The 2005 DMP suggested possible channel excavation and detention. A number of structures were known to have been inundated in the September 2010 storm event. Given the size of the watershed and magnitude of the flow above this location, major channelization and/or the construction of a levee would be required to protect the structures currently in the 100-year floodplain. There are approximately 104 structures in the 100-year FEMA floodplain on both the east and west bank of Little Nolan Creek in this area. Some of the most significant flooding occurs on Pilgrim Drive (see picture below). The most cost effective flood control improvement in this area would likely be a levee. However, due to the expense of building such a flood control structure, such a project likely would not be considered feasible or cost effective. It is recommended that this area be identified for possible repetitive loss grants.

This reach of Little Nolan Creek has opportunities for adding vegetative and bank stabilization that would be advantageous from an environmental and water quality standpoint.

Finally, a Letter of Map Revision is being developed for this area to more-accurately represent the FEMA 100-year floodplain to correct past modeling issues.

Perceived Benefit: Although major floodplain improvements are not recommended for this area, vegetative and channel bank restoration and stabilization would enhance the environmental and aesthetic characteristics of the surrounding area.

Summary: Major engineering and construction capital improvements projects are not recommended for this area given the magnitude and complexity of preventing residential flooding. However, Little Nolan Creek should be considered for channel bank restoration and vegetative improvements to enhance aesthetic and environmental considerations.

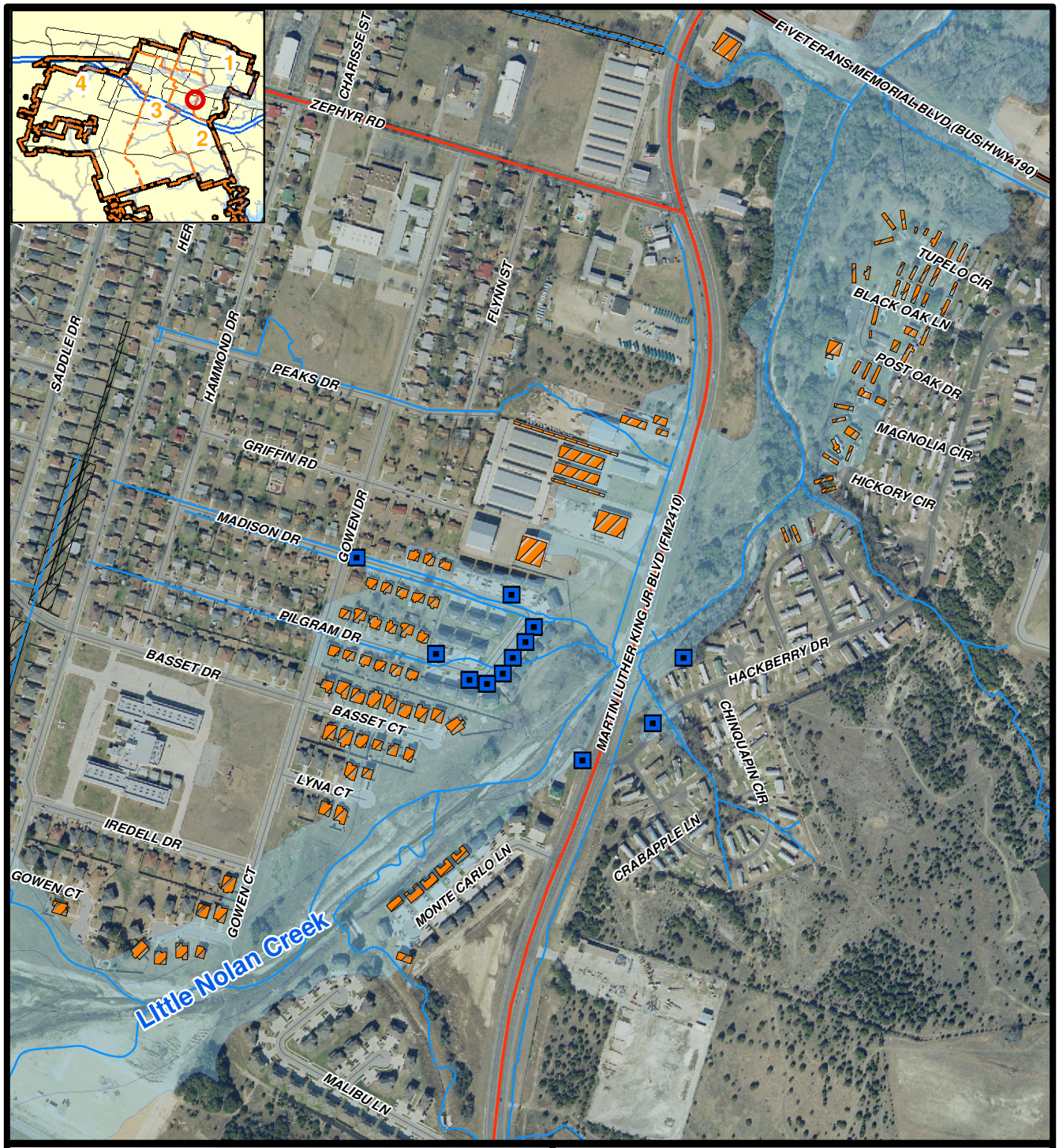
Table 22
Runoff Estimate (HEC-HMS)

Drainage Area (mi^2)	10-Yr	50-Yr	100-Yr
	(cfs)		
9.6	11,383	16,110	18,393

Table 23
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	5	0	0	5	Uncertain

City staff indicating approximate high-water mark elevation for residential property on the west bank of Little Nolan Creek.



Legend

- House Flooding
- Houses in 100-yr Floodplain
- 100-yr FEMA Floodplain Zone AE
- Stream Centerline

N

0 600 1,200 Feet

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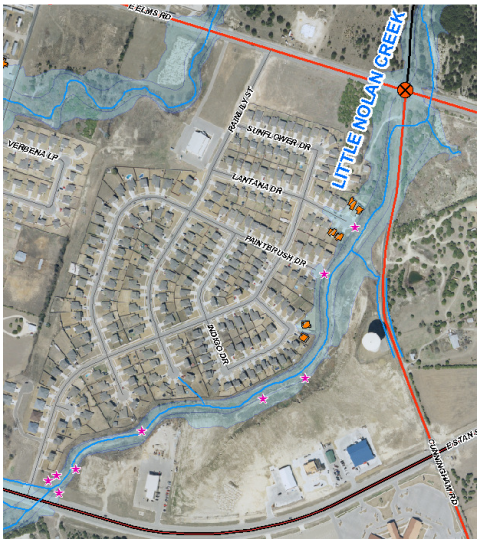
2012-14 Pilgrim Drive Residential Flooding

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 600 feet
Prepared by: D. Harris	Date: March, 2011
File: 2010-14 Pilgrim Drive Residential Flooding.mxd	

2012-19 Little Nolan Creek Stream Restoration



Site Description: This reach of Little Nolan Creek is between East Stan Schlueter Loop and East Elms Road. Some bank erosion and erosion at some of the outfalls were documented after the September 2010 storm, in particular just downstream of East Stan Schlueter Loop. Upon a field visit to the site, it was determined that the bank erosion and outfall erosion are relatively minor. However, this reach does have the potential to experience more severe erosion in the future, in particular as the watershed upstream of this site develops with increased peak flow and runoff volume. There are 6 structures within the FEMA 100-year floodplain; however, no structures were reported to have flooded in the September 2010 event. Although erosion is only of moderate severity, soil stabilization at the outfalls of this project should be considered using fill and rock riprap.

Perceived Benefit: Repairing the outfall will halt more severe erosion and soil discharge.

Summary: Bank erosion is only moderately low severity; however, there is some moderately severe erosion at a few of the outfalls. Repairing the outfalls would be relatively inexpensive and should be considered, but overall this project is considered a low priority. This area has the potential for severe bank erosion to occur and should be monitored.

Table 23
Ranking Summary

Priority	Public Safety	Transportation Access	Property Damage	Environmental Considerations	Engineering Economy	Ranking Sum	Approximate Cost
	0	0	0	2	2	4	200,000

Legend

- Infrastructure Failures from Sept '10
- Road Closures
- Houses in 100-yr Floodplain
- Zone AE
- Stream Centerline

0 500 1,000 Feet

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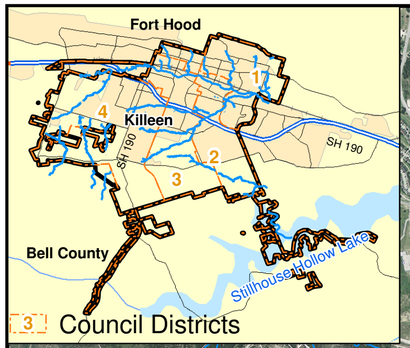
2012-19
Little Nolan Creek
Stream Restoration

Prepared for: City of Killeen	
Job No.: 100018246	Scale: 1 inch = 500 feet
Prepared by: D. Harris	Date: May, 2011
File: 2010-19 Little Nolan Creek Repair.mxd	

Appendix C

Overview Map

Appendix C
City of Killeen Overview
Drainage Master Planning



Legend

- #3 CIP Priority Recommended for Funding*
- CIP Storm Drain & Ditch Neighborhood Drainage
- CIP Stream Repair and Floodplain Improvements
- CIP Schematic Regional Detention Ponds
- Conceptual Regional Detention Location
- Existing Regional Detention Ponds
- Infrastructure Failures from Sept '10
- Parks from Comprehensive Plan Map
- Yard Flooding
- Other
- House Flooding
- Erosion
- Street Flooding
- Road Closures
- City Limits

Police and Fire Station Location

Note

- Fire Station
- Police Station

* See Table E-1 for a Summary of the CIPs Recommended for Capital Improvement Bond Funding

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Appendix C
City of Killeen Overview
Drainage Master Planning

0.5 0 0.5 Miles

Scale: 1 inch = 0.5 miles

Date: July, 2012

File: Appendix C Overview Map 24 X 18.mxd