1. Administrative Details

Proposal Name: Waco Lake Embankment Stabilization Project

by Agency: City of Waco

Locations: TX

Date Submitted: 08/20/2018

Confirmation Number: 99c9953e-ef84-41fd-bbcf-20f67966e086

Supporting Documents

File Name	Date Uploaded
Support - Section 7001 - Waco Lake - August 20.pdf	08/20/2018
Vicinity Map.pdf	08/20/2018
Lake Shore Drive Task 2 Report - Slope Protection and Drainage.pdf	08/20/2018

2. Provide the name of the primary sponsor and all non-Federal interests that have contributed or are expected to contribute toward the non-Federal share of the proposed feasibility study or modification.

Sponsor	**Letter of Support**
City of Waco(Primary)	The City of Waco Mayor, Council and City management s upport the project. On several occasions, the project has b een presented to the City Council. The City has financed t he cost of extensive geotechnical and engineering evaluatio ns. These evaluations identified the project and its prelimi nary cost.

3. State if this proposal is for a feasibility study, a modification to an authorized USACE feasibility study or a modification to an authorized USACE project. If it is a proposal for a modification, provide the authorized water resources development feasibility study or project name.

[x] Feasibility Study

4. Clearly articulate the specific project purpose(s) of the proposed study or modification. Demonstrate that the proposal is related to USACE mission and authorities and specifically address why additional or new authorization is needed.

The purpose of Waco Lake Embankment Stabilization Project is to stabilize identified risks associated with b ank failures, both shallow and deep failure. The project is related to the Corps' primary mission of flood risk management and further related to recreation. The authorization is needed to allow the Corps of Engineers t o team with the City of Waco in addressing the Waco Lake bank instabilities. The benefits of the project rel ate to avoiding a catastrophic embankment failure that would result in massive costs for its replacement, avo id the potential flood risks and changes to flooding patterns that would result from loss of the embankment, and, significantly, avoid the potential loss of human life associated with sudden and total failure of Lake Sho re Drive (a major arterial roadway without an existing, direct alternative route). The project would also avoi d the potential negative impacts and requirement to restore the established Waco Lake ecosystem. The need and purpose of the project is discussed in detail as part of the geotechnical and engineering preliminary evaluations completed in 2016 by the City of Waco. These technical reports provide results of the stability e valuations, risk considerations for both shallow- and deep-failures, a review of options for control, and prelim inary recommendations of control methods, including phasing and cost estimates. The City of Waco staff an d consultants have provided copies of these reports to Fort Worth District and Southwest Division.

5. To the extent practicable, provide an estimate of the total cost, and the Federal and non-Federal share of those costs, of the proposed study and, separately, an estimate of the cost of construction or modification.

	Federal	**Non-Federal**	**Total**
Study	$50,000	$75,000	$125,000
Construction	$21,750,000	$7,250,000	$29,000,000

Explanation (if necessary)

The preliminary evaluation reports prepared in 2016 provided estimates of project costs. The costs are nece ssarily preliminary but provide a reasonable expectation of project cost. The costs were broken-out by phas es. Total Project Cost:$29,000,000 Phase 1: Immediate roadway repairs, for safety - $380,000 (COMPLE TED) Section 7001 - Feasibility Study Estimated Cost: $125,000 Remaining Construction phases: Phase 2: Horizontal drains - $2,000,000 Phase 3: Soil nails_passive anchors in critical areas - $11,000,000 Phase 4: Soil nails_passive anchors in secondary areas - $9,000,000 Phase 5: Soil nails_passive anchors in final areas - $7,000,000

6. To the extent practicable, describe the anticipated monetary and nonmonetary benefits of the proposal including benefits to the protection of human life and property; improvement to transportation; the national economy; the environment; or the national security interests of the United States.

It is difficult to assign a monetary cost for the repair, replacement that result from a future, catastrophic (de ep failure) loss of the Lake embankment in the project area: replacement of the Lake embankment to pre-ex isting grade, construction of a new roadway, replacement of access to Lake recreational facilities, and restorin g the Lake ecosystem. A rough estimate of the monetary loss avoided would approach $100,000,000 or more. A major project benefit is protection of human life endangered by either the continued minor failures* or, mo re seriously, the catastrophic loss of Lake Shore Drive, the major Waco roadway located on the embankment. With the loss of the western embankment, there would be significant changes in flooding patterns that would endanger property. Lake Shore Drive is a major and only arterial for traffic moving around Waco Lake; it s protection and maintaining the minor roadways to access the Corps' recreational areas along Lake Shore D rive are the transportation benefits The City of Waco is a major national tourist attraction, Lake Waco pr ovides part of the reason that an estimated two million people from throughout the country visit Waco each year. The ecosystem of Waco Lake particularly in vicinity of the project would be highly impacted. As a whole, the effects on the Lake Waco aquatic environment would be initially dramatic and would linger for ye ars unless restored. _____ *In recent years, the stretch of Lake Shore Drive between Mt. Carmel Dri ve and Koehne Park has been the scene of numerous crashes. Many of these crashes, according to a report pr ovided by the City of Waco, involved a single vehicle which lost control as it traveled southbound (SB) down hill and through a curve on the segment of Lake Shore Drive south of Mt. Carmel Drive. Freese & Nichols, 2 016.

7. Does local support exist? If 'Yes', describe the local support for the proposal.

[x] Yes

Local Support Description

The City of Waco strongly supports the project with the added support of McLennan County. The City's Mayor, Council Members and City Manager recognize the critical need and support the project. The City's Chamber of Commerce, Industrial Development Group and others also support the project.

8. Does the primary sponsor named in (2.) above have the financial ability to provide for the required cost share?

[x] Yes

Primary Sponsor Letter of Support

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Support - Section 7001 - Waco Lake - August 20.pdf

CITY OF WACO

City Manager's Office
Post Office Box 2570
Waco, Texas 76702-2570
254 / 750-5640
Fax: 254 / 750-5880
www.waco-texas.com

August 20, 2018

COL Kenneth N. Reed
Commander
U.S. Army Engineer Corps of Engineers
819 Taylor Street (Room 3A32)
Fort Worth, TX 76102

RE: Letter of Support for Section 7001 Request for Project Modification
Waco Lake Embankment Stabilization Project

Dear Colonel Reed:

The City of Waco supports the referenced request for modifications to Waco Lake that would stabilize the embankment in the vicinity of Lake Shore Drive. The attached exhibit shows the general vicinity of the stabilization project.

The City of Waco funded the initial engineering and geotechnical evaluations of the instability of the embankment. These studies identified both shallow- and deep-failure risks associated with the embankment in this area. The preliminary studies, which are included as reference with the Section 7001 proposal submittal, identified the risks and proposed a series of corrective actions. The total cost of the recommended project is estimated at $29,000,000. The Section 7001 request recognizes the City of Waco as the primary sponsor.

The City of Waco intends to serve as the sponsor for the project. Should the request be included in the Corps' main report table in the Report to Congress on Future Water Resources Development, the City Staff recognizes that this does not provide Congressional authorization or federal funding for the project and that Congress must authorize and fund the project.

We appreciate the support of the Fort Worth District and Southwest Division Staff in providing guidance and answering questions regarding the Section 7001 process and this request. Please contact our City Manager, Wiley Stem III, at the number above or J. Tom Ray, the City's Consultant at (254) 855-0990 for further information or assistance.

Sincerely,

Wiley Stem III
City Manager

Attachment

Map Document

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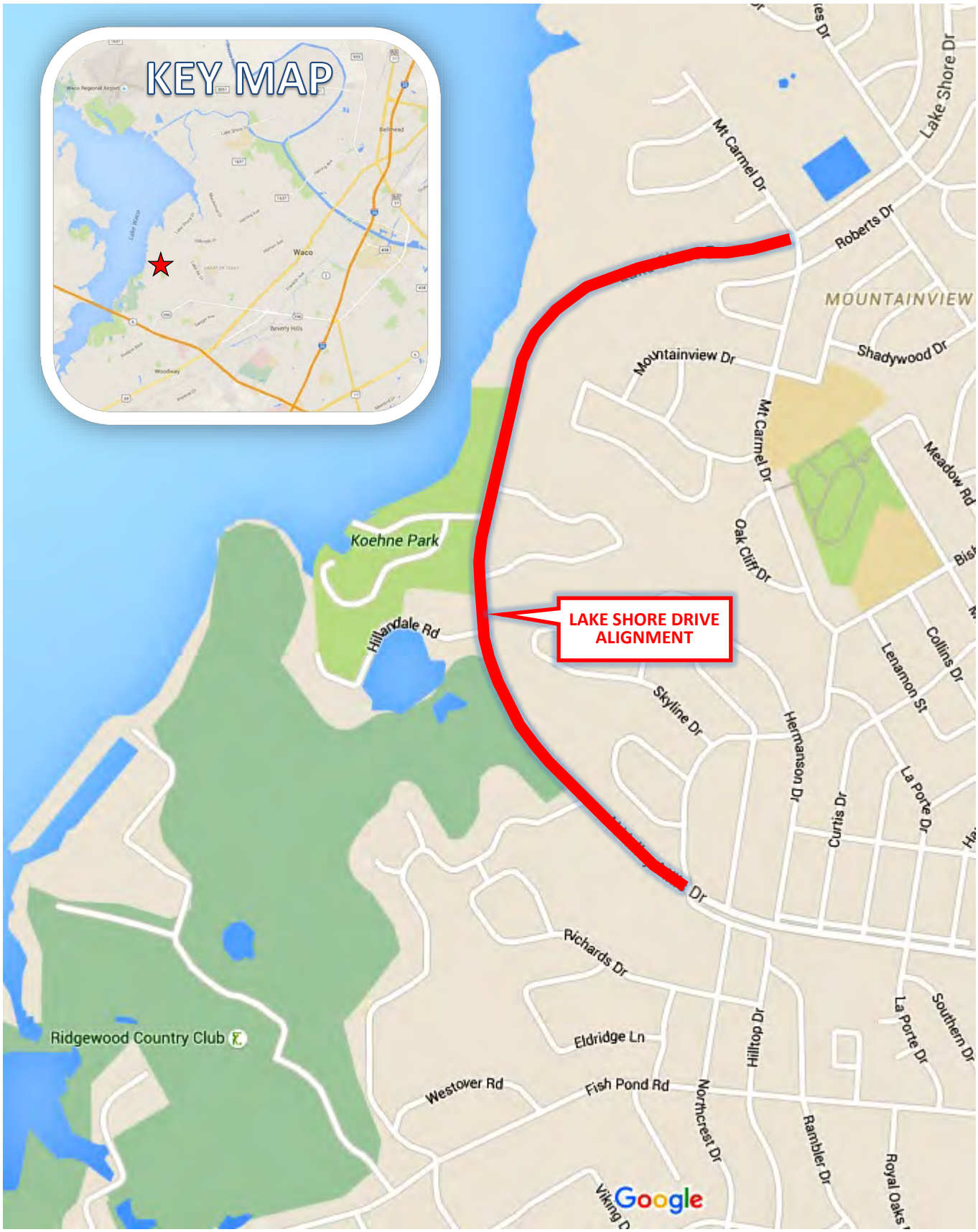
Vicinity Map.pdf



FNI PROJECT: WAL15259	FREESE AND NICHOLS	CITY OF WACO **LAKE SHORE DRIVE**	**FIGURE A.1**
FIL T:\2.0 STUDY\2.04 Study-Rpts\Task 3			
DATE: OCT 21, 2015	4055 INTERNATIONAL PLAZA, STE 200 FORT WORTH, TX 76109	**VICINITY MAP**	
PREPARED: MTM			

Additional Proposal Information

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Lake Shore Drive Task 2 Report - Slope Protection and Drainage.pdf

LAKE SHORE DRIVE IMPROVEMENTS

TASK 2 OF 4 Slope Protection and Drainage

THE WALLACE GROUP
engineers architects surveyors
A CP&Y COMPANY

FREESE AND NICHOLS

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

THE WALLACE GROUP
engineers architects surveyors
A CP&Y COMPANY

LAKE SHORE DRIVE
SLOPE PROTECTION AND DRAINAGE STUDY

Prepared for:

City of Waco

JULY 2015

STATE OF TEXAS
JUSTIN T. OSWALD
113171
LICENSED
PROFESSIONAL ENGINEER
06/02/2017

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

STATE OF TEXAS
DAVID L. MAREK
83327
REGISTERED
PROFESSIONAL ENGINEER
6/02/2017

THE WALLACE GROUP, INC
TEXAS REGISTERED
ENGINEERING FIRM
F-54

Prepared by:

FREESE AND NICHOLS, INC.
4055 International Plaza, Suite 200
Fort Worth, Texas 76109
817-735-7300

WAL15259

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APPENDICES

Appendix A. Exhibits
- Exhibit 1 – Drainage Area Map
- Exhibit 2 – Existing Conditions
- Exhibit 3 – Drainage Recommendations

Appendix B. Data
- Lake Shore Drive Drainage Cost Estimate
- CulvertMaster Output
- W-333 6” Water Record Drawing

EXECUTIVE SUMMARY

The Wallace Group (TWG), in association with Freese and Nichols, Inc. (FNI), was selected by the City of Waco to identify methods and associated costs to improve traffic safety, address drainage and erosion issues, determine required slope stabilization improvements, and restore scenic views of Lake Waco along the segment of Lake Shore Drive between Mt. Carmel Drive and Bishop Drive.

Task 2 under this contract focuses on the existing storm drainage system that affects Lake Shore Drive. This study task is being undertaken to determine if the existing storm drainage system has sufficient capacity to adequately convey design storms. Additionally, characteristics of the existing drainage were studied to determine if there are any erosive effects from excess stormwater runoff that are impacting Lake Shore Drive.

The existing drainage system was documented from City records and field observations. As part of the assessment, the capacity of the existing infrastructure was calculated according to City of Waco criteria. Areas of erosion were noted in the field and recommendations for proposed improvements were developed.

The existing drainage system was found to have adequate capacity per City of Waco criteria. Several culverts and ditches had calculated velocities that are considered to be erosive even though capacity was adequate. Large-scale erosion due to runoff was not noted during the field visits, but several small-scale erosion concerns were identified.

The recommended improvements for Lake Shore Drive include: spot repair of erosion on the road embankment, concrete lining of an existing roadside ditch, protection of a creek and utility with boulder drop structures, repair of an existing concrete channel, clearing the obstructed roadside ditches, and cleaning and inspecting silted culverts. The total estimated cost of the recommended Lake Shore Drive improvements is $256,000. Additional recommendations are provided for drainage concerns outside the project limits. These recommendations include constructing a grouted rip rap flume and protecting an incised channel with boulder drop structures. The total estimated cost of the offsite recommended improvements is $85,000. The improvements recommended in this study deal only with localized drainage issues and not with the global stability issues investigated in subsequent Technical Memos under this contract. Additional improvements which may be recommended for Lake Shore Drive to resolve slope stability issues will be discussed in those subsequent Technical Memos.

1.0 EXISTING DRAINAGE INFRASTRUCTURE

The project limits extend along Lake Shore Drive from its intersection with Mt. Carmel Drive to Bishop Drive. The total length of the project is approximately 1.2 miles. The majority of the road through the project area was constructed on steep fill slopes of approximately 2.5:1 (H:V). Lake Shore Drive is a curb and gutter section at the intersection with Mt. Carmel Drive which transitions to a paved shoulder section after approximately 500 feet. The remainder of the project consists of a paved shoulder which drains either to a roadside ditch or down the embankment slope of the road. The pavement is generally crowned, though the horizontal location of the crown is not consistent along the length of the project.

The areas on the uphill (east) side of the road drain to a network of roadside ditches and culverts which discharge through culverts beneath the embankment to the downhill (west) side. The drainage on the downhill side of the road is generally unimproved from a natural state. An exception to this is the concrete channel constructed at the toe of the fill slope near Mt. Carmel Drive.

From the City of Waco's GIS information, three culverts were identified that discharge water from the east side of Lake Shore Drive to the west towards the lake. Further field investigation revealed two additional culverts that discharge towards the lake and two culverts that are installed parallel to the roadways. These culverts are identified on Exhibit 1 as CUL 1 through CUL 7. Limited field surveying of CUL 1 – CUL 3 was conducted to accurately measure the flowlines and sizes of culverts. The drainage from the watershed is conveyed to these locations via a series of storm inlets, pipes, and channels.

2.0 REVIEW OF EXISTING DRAINAGE CRITERIA: CITY OF WACO

The City of Waco's Storm Drainage Design Manual (SDDM) written in 1959 by Forrest and Cotton, Inc. is utilized for determining the design storm frequency which is to be evaluated for the capacity of culverts, curb inlets and channels. Table 1 outlines the following critical return periods:

Table 1: City of Waco Design Storm Frequency

Facility	Contributing Watershed (acres)	Time of Concentration (min)	Design Frequency (Years)
Storm Sewer	Residential w/ scattered business or commercial	30	2
Culverts	<100	30	5
Channel	<100	30	5
Culverts	>100	45	10

Source: SDDM, 1959.

Recently, Stormwater Management Regulations were approved by the City of Waco. In the case of curb inlets and roadside channels, the design frequency was increased to consider the 5-year design storm. Culvert design frequencies were not revised in the new regulations. Therefore, for this analysis, the selected design frequency is as outlined in the table below. In addition to the frequencies stated below, a 25-year frequency check was calculated for all culverts.

Table 2: Selected Design Frequency

Facility	Contributing Watershed (acres)	Time of Concentration (min)	Design Frequency (Years)
Storm Sewer	Residential w/ scattered business or commercial	30	5
Culverts	<100	30	5
Channel	<100	30	5
Culverts	>100	45	10

3.0 DETERMINATION OF STORMWATER DISCHARGES

A base map consisting of the current City of Waco aerial contours, roads, and existing storm drainage system was compiled to evaluate the watershed contributing to the culverts and channels along Lake Shore Drive. The base map is included as Exhibit 1 in Appendix A. Site visits to the subject watersheds were conducted to evaluate runoff parameters at critical locations.

Due to the size of the watersheds, the Rational Method was used to determine the stormwater runoff peak discharges. Each watershed had a time of concentration calculated based on existing City of Waco methodology. A minimum time of concertation of five minutes was utilized. Using the City of Waco Intensity Duration Frequency curves, intensity for each critical storm event was calculated. For the watersheds that comprise residential uses or undeveloped areas, a runoff value ("C" coefficient) of 0.4 was utilized. For those watersheds that are entirely roadway, a runoff value of 0.95 was used.

A summary of the discharges to each drainage feature are indicated in the table on Exhibit 1 in Appendix A.

4.0 ANALYSIS OF DRAINAGE FEATURES

The existing channels were analyzed to determine the capacity of the ditches. For each channel, a 3:1 sideslope and depth based on City of Waco aerial topography was assumed. The slope of each channel was also calculated using the City's aerial data. Using the FlowMaster program, the capacity of each channel was calculated using a Manning's n value of 0.04. It should be noted that for full flow capacity two of the identified channels have a velocity that would potentially create erosion of the streambed.

Culvert capacities were analyzed using the CulvertMaster program. For Culverts 1 through 3, surveyed flowline data and top of roadway information was used. For the remaining four culverts, assumed flowlines, length, and top of roadway elevations were determined from City of Waco aerial information and field observations. At each culvert, the outlet was assumed to have a free discharge based on the lack of defined channels on the downstream slope.

From the analysis, the headwater on the 5-year storms did not overtop the roadway. The 25-year check storm was analyzed which likewise did not overtop the roadway. The culvert analysis identified outlet velocities that could cause erosive conditions for all culverts except Culvert 5. Though the culverts are adequate for discharging the expected peak stormwater flows without impacting roadway conditions,

these results indicate there is a potential for the downstream erosion to occur. The culvert results shown on Exhibit 1 in Appendix A are reproduced in Table 3.

Table 3: Culvert Results

Culvert	Size	Entrance Flowline (ft)	Adjacent Pavement Elevation (ft)	HW_5 (ft)	HW_{25} (ft)	V_5 (OUT) (fps)	V_{25} (OUT) (fps)
1	52"	502.64	536	506.03	506.94	9.05	9.97
2	30"	485.32	504	487.67	488.11	16.21	17.52
3	66"	481.80	504	487.87	489.24	14.41	15.50
4	4'x3'	540	560	542.41	543.26	9.22	10.50
5	2-24"	600	604	601.30	601.54	1.75	2.37
6	42"	530	532	530.73	530.85	7.84	8.59
7	42"	506	512	507.30	507.52	7.03	7.58

5.0 IDENTIFICATION OF EROSION

Multiple field visits were conducted (June 23, June 29, July 10, and July 21, 2015) to evaluate and observe the existing drainage infrastructure, existing erosion, and erosion potential. Both shoulders of the roadway were walked to observe the roadside ditches and embankments. Where feasible, the toes of the roadway embankments and culvert outlets were observed. In addition, the adjacent drainage outfalls within the contributing watershed were observed where feasible. The drainage infrastructure that was observed in the field is noted on Exhibit 1 in Appendix A. The following list summarizes the existing conditions noted based on our observations. These areas of interest are shown on Exhibit 2 in Appendix A. The numbering used in this section corresponds to the numbering of the photos on the exhibit.

1. None of the Lake Shore Drive culverts demonstrated significant erosion at either the inlets or outlets. Some minor erosion was noted around the edges of the headwall aprons which should be monitored as a maintenance activity. Appropriate protection at culvert outfalls allow the high velocity flow to transition to a more tranquil regime that does not cause erosion. Although the results in Table 3 indicate potentially erosive velocities at the culvert outlets, the lack of erosion observed at the outfalls indicates the existing erosion protection is adequate.

2. Two areas were noted where the slopes adjacent to the road had failed and are obstructing the ditches downhill of Rockview Drive and Skyline Drive. The area adjacent to Rockview Drive has a

temporary 12" PVC pipe acting as a culvert through the sloughed material. Due to these obstructions, the drainage does not perform to City standards in these areas.

3. The 2-24" RCP Culvert 5 crossing near the Ridgewood Drive intersection was partially silted. The adjacent downstream culvert under Ridgewood Drive was completely blocked by sediment. The cause of the blockage of the Ridgewood Drive culvert was unclear from field observations. The blocked culvert may have exacerbated siltation of the upstream 2-24" culverts by causing significant ponding of water and allowing silt to settle out.

4. The eastern ditch is eroding and downcutting near the Hillandale Road intersection. The ditch is steep (approximately 7% longitudinal slope) and is unprotected by vegetation or armoring material.

5. Numerous eroded rills were noted at the edge of the pavement on the road embankment. The erosion features were observed at the top of the embankment but generally had not extended down the entire slope. The soil along the shoulder is highly gravelly which may contribute to the erosion problem due to a lack of cohesion. In addition, the gravelly soil hinders the establishment of vegetation which would increase the resistance to erosion. There was no obvious concentration of flow evident that might be linked to this erosion. Some segments of what appear to be shallow asphalt curbing or a mow strip were observed along the edge of the west shoulder in one location that may be causing minor concentrated flow locations.

6. Significant erosion was noted downstream of the western curb inlet near the intersection of Mt. Carmel Drive. Due to the superelevation of the pavement in this area, most of the road drainage is directed towards this inlet. Due to the larger drainage area and the steep grade of the road, the inlet likely bypasses runoff to the shoulder which causes a concentrated discharge on the embankment. Additionally, it appears this inlet has settled unevenly with the road which may reduce the capture efficiency from its theoretical capacity.

7. A downstream portion of the concrete channel along the western toe of the embankment near Mt. Carmel Drive has failed. The channel appears to be failing from downstream to upstream due to successive headcutting of the unprotected downstream end. Portions of the channel have failed to the point of the channel lining being turned to rubble. Without repair, additional failure of upstream portions of the channel can be expected.

8. The creek along the toe of the western embankment north of Ridgewood Drive has eroded and exposed the trench of an existing utility which was originally buried in the flowline. It is believed the exposed utility is the 6" waterline denoted as W-333. It is possible the trench backfill was not properly compacted, but the slope of the creek is steep (approximately 7% longitudinal slope) which increases velocities and facilitates erosion. A large knickpoint was observed at the upstream limits of the exposed utility which indicates that erosion will likely continue upstream. Groundwater flow was observed in the trench. A copy of the record drawing for the waterline is included in Appendix B.

The following drainage and erosion concerns were observed in the field but are considered to be outside the Lake Shore Drive project area:

9. The flume downslope of Culvert 2 drains to a low area near the Koehne Park parking lot which does not appear to have positive drainage. This area likely ponds and then spills across the parking lot. This may result in some nuisance standing water after a rainfall event. This is not considered to be a significant concern.

10. A significant erosion issue was observed at the storm drain outfall located near the intersection of Mountainview Drive and Summit Ridge Street. The concentrated discharge from the storm drain has caused downcutting in the upland ravine. The channel appears to have incised by over 15 feet and portions of the drainage pipe have failed due to undermining. Similar failures may be present at the other outfalls in the upland areas due to the steep terrain.

11. There is a small diameter HDPE drainage pipe running down the surface of the steep slopes from Mt Rockwood Circle of the Mountainview Estates subdivision. This pipe is not buried and is secured to the ground by steel T-posts. A portion of the line has separated and eroded the slope and has exposed adjacent utilities.

12. Two of the small storm drain outfalls along the bluffs in the Lake Shore Drive watershed exhibited moderate erosion. These outfalls are located at Skyline Drive (denoted as DR-L on Exhibit 1) and Rockview Drive (denoted as DR-C on Exhibit 1). These outfalls are for minor systems each consisting of two inlets and a single storm drain line to drain the roads off the bluffs. For both outfalls, the slope adjacent to the headwalls was eroded by several feet leaving the headwall exposed. Small clearly defined channels have formed in the slopes downstream of the outfalls due to the concentrated discharge.

6.0 RECOMMENDATIONS

The Lake Shore Drive drainage systems investigation consisted of a desktop analysis and field assessment for capacity and erosion potential. The desktop analysis revealed the existing infrastructure meets City criteria and therefore no capacity increases are necessary. A number of erosion issues were identified based on field observations which are addressed by the following recommendations. These recommendations are depicted on Exhibit 3 in Appendix A.

1. It is recommended to perform spot repairs where rills have formed in the road embankment. The existing drainage on the embankment does not appear to be concentrated and therefore changes to the drainage system such as the addition of curb and gutter would not significantly reduce the formation of rills. Due to cost and required tree removal, it is not deemed practical to treat the entire embankment. It is therefore recommended that these erosion failures be repaired as a maintenance activity as they may appear. The recommended repair is described in further detail in Section 7 of this report. The estimated cost of these repairs is $69,000.

2. The eroding eastern ditch should be improved with a concrete flume. This flume will increase capacity, eliminate erosion potential, and simplify maintenance. This flume has been conceptually sized as 10’ wide with a 6” invert and would be approximately 300’ in length. The estimated cost of the flume is $39,000.

3. The creek containing the exposed utility near Ridgewood Drive should be backfilled and improved by constructing a series of boulder drop structures. Boulder drops are drop structures constructed of large stone riprap. The structures control the longitudinal grade of the creek and protect the creek from further erosion. They are also self-healing due to the ability of the stone to lock in to a new position should it be undermined and dislodged from its position. The proposed improvements are conceptualized as 500’ of improvements with 18” drops spaced at 20’ intervals. The estimated cost of the channel is $52,000. For the purposes of the cost estimate it was assumed a temporary construction easement would be acquired for portions of the creek outside of City right-of-way. An example detail of this concept is included below as Figure 1.

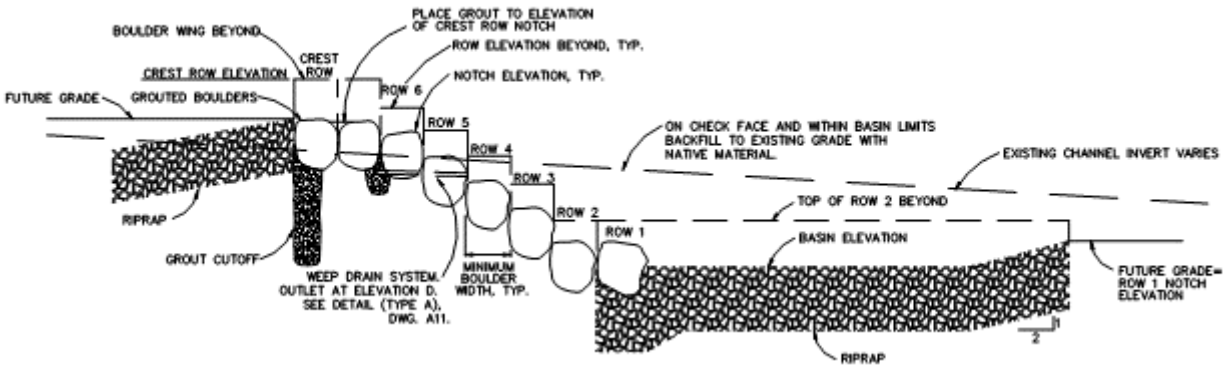


Figure 1: Boulder Drop Structure Detail

4. The erosion downstream of the western curb inlet near Mt. Carmel Drive should be repaired and a flume should be constructed to convey any bypass flow to the concrete channel at the toe of the embankment. This flume would be approximately 60' in length. In addition, the curb inlet tops should be reconstructed to match the road elevation. The estimated cost of the slope repair, flume, and inlet reconstruction is $13,000.

5. The damaged sections of the channel near Mt. Carmel should be removed and repaired to prevent further damage to the channel. Approximately 200' of channel are expected to need replacement. The downstream end of the reconstructed channel should be protected by rock rip rap or other revetment. This protection will serve to halt future failures due to headcutting. The estimated cost of the channel repair is $83,000.

6. The silted culverts located near Ridgewood Drive should be cleaned and inspected. Implementation of this recommendation is considered a maintenance task and no construction cost estimate is provided.

7. The ditches blocked by the slope failures and the temporary culvert should be cleared to allow proper drainage capacity. This work should not be undertaken until the cause of the failures has been addressed. Removal of this material may further destabilize the slope. Recommendations for the abatement of the slope movement will be addressed in a future section of this report.

The following recommendations address drainage issue outside of the Lake Shore Drive project area. These items are not considered critical to the drainage function of Lake Shore Drive, but they mitigate drainage concerns that were observed during this study.

8. The non-buried HDPE pipe along the slope of Mt Rockwood Circle should be replaced with a grouted rock riprap flume downstream of the level portions of the residential lots. It is anticipated that the steep slopes and limited access would make it difficult to bury the drainage line to provide proper support for the pipe. The grouted rock riprap flume requires minimal excavation and can be installed by hand or with light equipment. The estimated cost of the rock rip rap flume is $39,000.

9. The severely incised channel near Mountainview Drive should be protected by a series of boulder drops in a similar manner to the recommendation in Item 3 for the creek downstream of Ridgewood Drive. Due to the severity of the existing erosion, the soil and geomorphological conditions should be evaluated further during design. If the soil is excessively erosive the area may require traditional concrete armoring. The estimated cost of the boulder drop channel is $46,000. It was assumed a temporary construction easement would be acquired for portions of the improvements outside of City right-of-way and for construction access through the nearby vacant residential lot.

10. The two moderately eroded outfalls in the upland areas at Skyline Drive and Rockview Drive should be protected by the addition of riprap to prevent undermining of the headwall. The outfalls have caused small defined channels to form along the steep bluffs, but they are generally rocky or heavily vegetated which mitigates some of the erosion potential. These channels should be monitored periodically to evaluate if additional protection is warranted. Implementation of this recommendation is considered a maintenance task and no construction cost estimate is provided.

11. The 30” culvert outfall at Koehne Park should be evaluated for positive drainage by Park maintenance staff. If ponding water is evident, the outfall should be graded to provide proper drainage of this area. Additional rock rip rap may be appropriate if grading is performed. Implementation of this recommendation is considered a maintenance task and no construction cost estimate is provided.

An opinion of probable construction cost was developed for the recommended improvements. The removal of the hill failure and the cleaning of the culverts are considered incidental to other portions of the project and are not included in this estimate. The total estimated cost for the project within the Lake Shore Drive project limits is $256,000 which includes embankment spot repairs, the eastern ditch flume, the Mt. Carmel inlet flume, the Ridgewood Drive Creek protection, and repair of the concrete channel. The total estimated cost for the offsite projects including the Mt. Rockwood Circle rip rap flume and the Mountainview Drive channel protection is $85,000. The cost estimates are the total project cost and includes materials, testing, and engineering design services. It is expected that no right-of-way acquisition is required for these improvements. These estimates assume the construction is to be performed as part of a larger project to achieve ideal economies of scale in design and mobilization. The cost estimate break down is included in Appendix B of this report.

The projects within the Lake Shore Drive project limits are located within the area controlled by the United States Army Corps of Engineers (USACE) for operation of the Lake Waco Reservoir. The proposed improvements should be coordinated with the USACE Fort Worth District as the reservoir manager for approval and compliance with their policies. Some of the recommended improvements may be subject to the permitting requirements of Section 404 of the Clean Waters Act and Section 408 of Title 33 of the U.S. Code. These projects should be designed with these permit requirements in mind. Preliminary coordination with the USACE is anticipated at the conclusion of this study.

7.0 SLOPE EROSION RECOMMENDATIONS

The recommended repair consists of the installation of a high performance turf reinforcement mat (TRM) at the point of failure with percussion driven earth anchors. TRM is a geotextile mat designed to resist the shear force caused by runoff when vegetated through its woven plastic matrix. There are varying grades of TRM with high performance TRMs consisting of generally heavier materials, tighter weaves, and longer lasting materials. Typically the TRM is vegetated with a turf forming grass such as Bermuda grass.

The eroded area should first be backfilled with clean fill material and be well compacted. The eroded sections of the embankment show a significant percentage of gravel in the soil which may reduce its ability to resist erosion in comparison to a cohesive soil. In addition, the gravelly soil hinders plant growth. The repaired areas should be top-dressed with topsoil to improve vegetation establishment. Establishing vegetation increases the resistance to erosion. The TRM should be installed well outside the limits of the erosion and should be toed into the embankment at the top and bottom. The upslope toe should be

butted to the edge of the road or a concrete edge restraint should be constructed so that runoff cannot erode beneath or bypass the TRM. It is recommended that the TRM be installed with earth percussion anchors in addition to shallow pins. These anchors increase the pull-out resistance of the mat to improve the resilience of the installation, and they can be designed to protect the slope from shallow plane failures. It should be noted there may be additional failure modes identified in the geotechnical phases of this study that would not be corrected by the relatively shallow TRM installation. A detail for this type of installation is included as Figure 2.

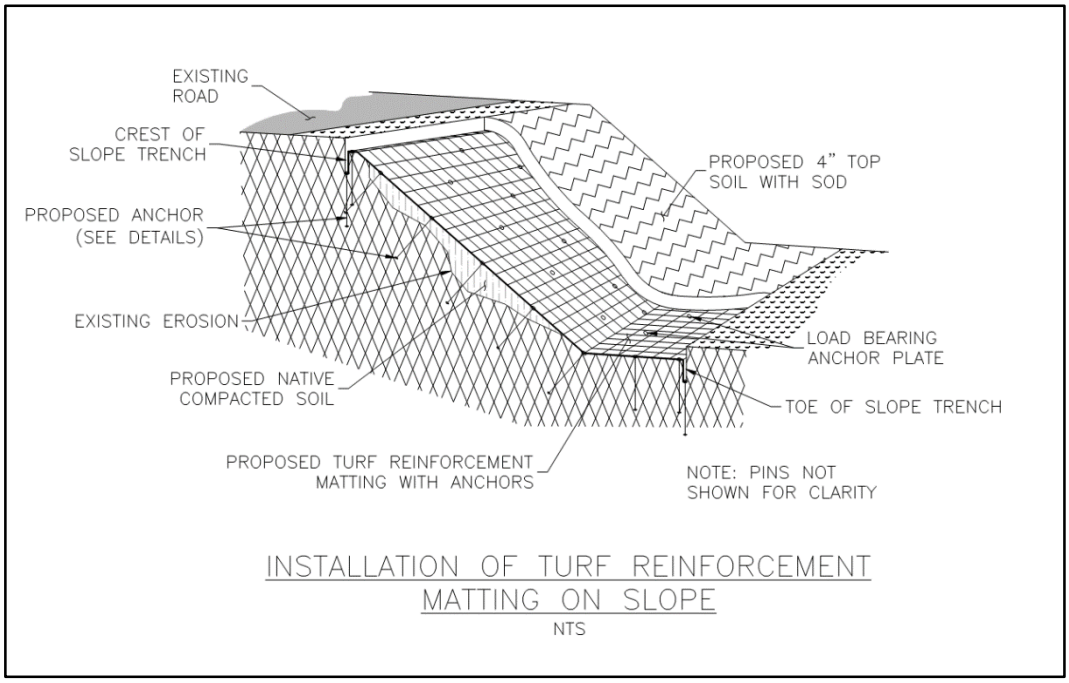
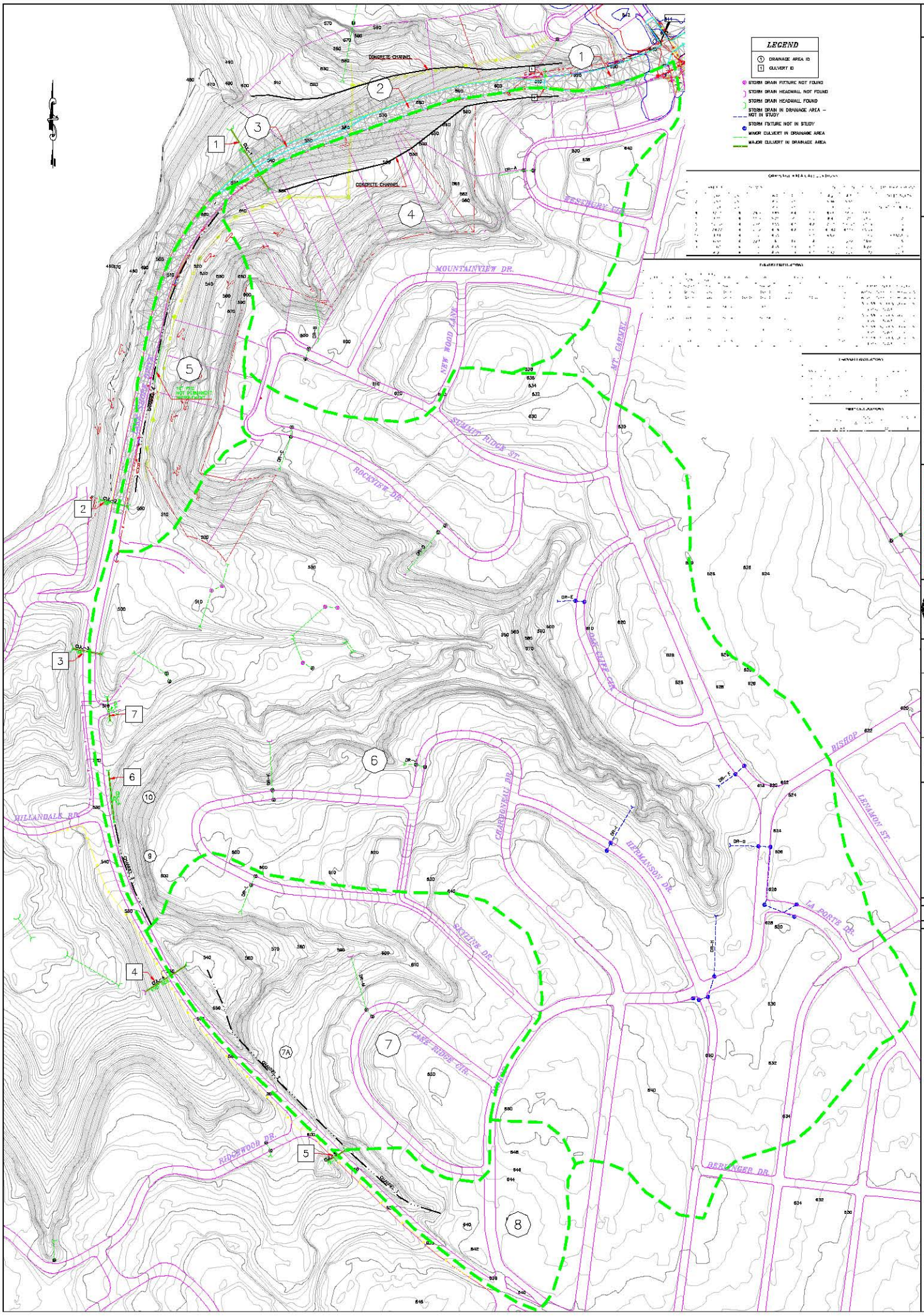


Figure 2: TRM Installation Detail

APPENDIX A
EXHIBITS


LEGEND
DRAINAGE AREA ID
CULVERT ID
STORM DRAIN FIXTURE NOT FOUND
STORM DRAIN HEADWALL NOT FOUND
STORM DRAIN HEADWALL FOUND
STORM DRAIN IN DRAINAGE AREA – NOT IN STUDY
STORM FIXTURE NOT IN STUDY
MINOR CULVERT IN DRAINAGE AREA
MAJOR CULVERT IN DRAINAGE AREA
CONCRETE CHANNEL
MOUNTAINVIEW DR.
NEW WOOD LANE
MT. CARMEL
SUMMIT RIDGE ST.
ROCKVIEW DR.
LAKE SHORE DRIVE
HILLANDALE DR.
CHARDONNAY DR.
HERMANSON DR.
BISHOP
LERMANON ST.
LA PORTE DR.
SKYLINE DR.
LAKE RIDGE CIR.
RIDGEWOOD DR.
BERLANGER DR.
CITY OF WACO
LAKE SHORE DRIVE TASK 2
EXHIBIT 1
DRAINAGE AREA MAP
THE WALLACE GROUP
engineers architects surveyors
A CPSY COMPANY
TBPE F-64
811

1. Minimal Erosion at 52" Outfall
7. Portions of Channel Buckling and Undermining
11. Non-buried HDPE Pipe
6. Severe Erosion Downstream of Inlet
2. Slope Failure and Temporary 12" Culvert
10. Incised Upland Channel
9. No Positive Drainage at Outfall
12. Headwall and Channel Eroded at Outfall
5. Eroded Slope
5. Asphalt Curbing May Concentrate Flow
5. Eroded Slope
1. Minor Erosion Around 66" Apron
4. Erosion Along Pavement
5. Exposed Water Meter in Eroded Slope
2. Slope Failure in Bar Ditch
12. Headwall and Channel Eroded at Outfall
8. Eroded Channel and Pipe Trench
3. Downstream Culvert Inlet Completely Silted
3. 2-24" Culvert Barrels
Lake Shore Dr
Hidden Cove Dr
Al Valley Mills Dr
LAKE SHORE DRIVE
Existing Conditions
City of Waco
McLennan County, Texas
0 250 500 Feet
Verbal Scale: 1" = 250'
Absolute Scale: 1 = 3,000
Date: July 2015
FN Job #: WAL15259
T:\SW\Memo\Exhibits\ExistingConditionsFinal.mxd
FREESE AND NICHOLS
4055 International Plaza, Suite 200
Fort Worth, Texas 76109-4895
p: (817) 735-7300 f: (817) 735-7491
Exhibit 2
Channel Erosion
Culverts and Storm Drains
Area of Slope Failure
Areas of Slope Erosion
Numbers Correspond to Section 5.0 Identification of Erosion in Report Text

Numbers Correspond to Section 6.0 Recommendations of Report Text

White Text Boxes Denote Area Outside of Project Limits for Lake Shore Drive

FREESE AND NICHOLS
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

N W E S

CITY OF WACO
LAKE SHORE DRIVE

Drainage Recommendations

FN JOB NO	WAL15259
FILE	T:/SW/Memo/Exhibits
DATE	July 1, 2015
SCALE	1:6,000
DESIGNED	JTO
DRAFTED	SRD

3

EXHIBIT

APPENDIX B
DATA

Lake Shore Drive Drainage

Opinion of Probable Construction Cost

City of Waco

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
WAL15259	JTO	SKH	July 30, 2015

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Embankment Spot Repairs (20 Repairs 20'x20' Ea)					**$69,000**
	Traffic Control	1	LS	$1,000.00	$1,000
	Scarify, Backfill, and Compact	125	CY	$30.00	$3,750
	4" Topsoil and Sod	900	SY	$5.50	$4,950
	High Performance TRM with Anchors	900	SY	$30.00	$27,000
	Misc Pavement	400	LF	$15.00	$6,000
	Contingency (30%)	1	LS	$12,810.00	$12,810
	Engineering (15%)	1	LS	$8,326.50	$8,327
	Staking, Testing (10%)	1	LS	$5,551.00	$5,551
Eastern Ditch Flume					**$39,000**
	Traffic Control	1	LS	$1,000.00	$1,000
	Misc Grading	1	LS	$500.00	$500
	Concrete Flume	300	LF	$75.00	$22,500
	Contingency (30%)	1	LS	$7,200.00	$7,200
	Engineering (15%)	1	LS	$4,680.00	$4,680
	Staking, Testing (10%)	1	LS	$3,120.00	$3,120
Ridgewood Drive Creek Protection					**$52,000**
	Clearing and Grubbing	1	LS	$8,000.00	$8,000
	Boulder Drops (20' Spacing / 2.0 CY EA)	50	CY	$250.00	$12,500
	Backfill Utility Trench	150	CY	$20.00	$3,000
	Misc Utility Relocation	1	LS	$8,000.00	$8,000
	Temporary Construction Easement	1	LS	$1,000.00	$1,000
	Contingency (30%)	1	LS	$9,450.00	$9,450
	Engineering (15%)	1	LS	$6,292.50	$6,293
	Staking, Testing (10%)	1	LS	$4,195.00	$4,195
Mt. Carmel Inlet Flume					**$13,000**
	Traffic Control	1	LS	$500.00	$500
	Clearing and Grubbing	1	LS	$1,200.00	$1,200
	Reconstruct Inlet Top	2	EA	$1,500.00	$3,000
	Concrete Flume	60	LF	$55.00	$3,300
	Contingency (30%)	1	LS	$2,400.00	$2,400
	Engineering (15%)	1	LS	$1,560.00	$1,560
	Staking, Testing (10%)	1	LS	$1,040.00	$1,040
Concrete Channel Repair					**$83,000**
	Misc Subgrade and Grading	450	SY	$12.00	$5,400
	Demo Existing Channel Lining	450	SY	$12.00	$5,400
	Concrete Channel Lining	450	SY	$65.00	$29,250
	18" Rock Rip Rap Toe	75	CY	$150.00	$11,250
	Contingency (30%)	1	LS	$15,390.00	$15,390
	Engineering (15%)	1	LS	$10,003.50	$10,004
	Staking, Testing (10%)	1	LS	$6,669.00	$6,669
Project Total					**$256,000**

Notes:

Lake Shore Drive Offsite Drainage

Opinion of Probable Construction Cost

City of Waco

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
WAL15259	JTO	SKH	July 30, 2015

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Mt. Rockwood Circle Grouted Riprap Flume					**$39,000**
	Misc Grading	1	LS	$5,000.00	$5,000
	Grouted 12" Rock Rip Rap Flume	70	CY	$275.00	$19,250
	Contingency (30%)	1	LS	$7,275.00	$7,275
	Engineering (15%)	1	LS	$4,728.75	$4,729
	Staking, Testing (10%)	1	LS	$3,152.50	$3,153
Mountainview Drive Incised Channel Protection					**$46,000**
	Clearing and Grubbing	1	LS	$8,000.00	$8,000
	Boulder Drops (20' Spacing / 4.0 CY EA)	50	CY	$250.00	$12,500
	Misc Grading	1	LS	$7,000.00	$7,000
	Temporary Construction Easement	1	LS	$1,000.00	$1,000
	Contingency (30%)	1	LS	$8,250.00	$8,250
	Engineering (15%)	1	LS	$5,512.50	$5,513
	Staking, Testing (10%)	1	LS	$3,675.00	$3,675
Project Total					**$85,000**

Notes:

Culvert Designer/Analyzer Report
Culvert 1

Q_5

Analysis Component			
Storm Event	Design	Discharge	49.80 cfs

Peak Discharge Method: User-Specified			
Design Discharge	49.80 cfs	Check Discharge	73.71 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Design Storm.			
Discharge	49.80 cfs	Bottom Elevation	500.87 ft
Depth	1.06 ft	Velocity	9.39 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-48 inch Circular	49.80 cfs	506.03 ft	9.05 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 1

Component:Culvert-1

Culvert Summary			
Computed Headwater Elev:	506.03 ft	Discharge	49.80 cfs
Inlet Control HW Elev.	505.74 ft	Tailwater Elevation	501.93 ft
Outlet Control HW Elev.	506.03 ft	Control Type	Entrance Control
Headwater Depth/Height	0.85		

Grades			
Upstream Invert	502.64 ft	Downstream Invert	500.87 ft
Length	258.12 ft	Constructed Slope	0.006857 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	1.81 ft
Slope Type	Steep	Normal Depth	1.81 ft
Flow Regime	Supercritical	Critical Depth	2.12 ft
Velocity Downstream	9.05 ft/s	Critical Slope	0.003973 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	4.00 ft
Section Size	48 inch	Rise	4.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	506.03 ft	Upstream Velocity Head	0.85 ft
Ke	0.50	Entrance Loss	0.42 ft

Inlet Control Properties			
Inlet Control HW Elev.	505.74 ft	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	12.6 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Designer/Analyzer Report
Culvert 1

Q25

Analysis Component			
Storm Event	Check	Discharge	73.71 cfs

Peak Discharge Method: User-Specified			
Design Discharge	49.80 cfs	Check Discharge	73.71 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Check Storm.			
Discharge	73.71 cfs	Bottom Elevation	500.87 ft
Depth	1.39 ft	Velocity	10.60 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-48 inch Circular	73.71 cfs	506.94 ft	9.97 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 1

Component:Culvert-1

Culvert Summary			
Computed Headwater Elev	506.94 ft	Discharge	73.71 cfs
Inlet Control HW Elev.	506.69 ft	Tailwater Elevation	502.26 ft
Outlet Control HW Elev.	506.94 ft	Control Type	Entrance Control
Headwater Depth/Height	1.07		

Grades			
Upstream Invert	502.64 ft	Downstream Invert	500.87 ft
Length	258.12 ft	Constructed Slope	0.006857 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	2.28 ft
Slope Type	Steep	Normal Depth	2.28 ft
Flow Regime	Supercritical	Critical Depth	2.60 ft
Velocity Downstream	9.97 ft/s	Critical Slope	0.004614 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	4.00 ft
Section Size	48 inch	Rise	4.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	506.94 ft	Upstream Velocity Head	1.13 ft
Ke	0.50	Entrance Loss	0.57 ft

Inlet Control Properties			
Inlet Control HW Elev.	506.69 ft	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	12.6 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Designer/Analyzer Report
Culvert 2

Analysis Component			
Storm Event	Design	Discharge	19.60 cfs

Q_5

Peak Discharge Method: User-Specified			
Design Discharge	19.60 cfs	Check Discharge	25.60 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Design Storm.			
Discharge	19.60 cfs	Bottom Elevation	475.14 ft
Depth	0.86 ft	Velocity	7.63 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-30 inch Circular	19.60 cfs	487.77 ft	16.51 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 2

Component:Culvert-1

Culvert Summary				
Computed Headwater Elev:	487.77 ft		Discharge	19.60 cfs
Inlet Control HW Elev.	487.52 ft		Tailwater Elevation	476.00 ft
Outlet Control HW Elev.	487.77 ft		Control Type	Entrance Control
Headwater Depth/Height	0.98			

Grades				
Upstream Invert	485.32 ft		Downstream Invert	475.14 ft
Length	152.00 ft		Constructed Slope	0.066974 ft/ft

Hydraulic Profile				
Profile	S2		Depth, Downstream	0.73 ft
Slope Type	Steep		Normal Depth	0.73 ft
Flow Regime	Supercritical		Critical Depth	1.50 ft
Velocity Downstream	16.51 ft/s		Critical Slope	0.005034 ft/ft

Section				
Section Shape	Circular		Mannings Coefficient	0.013
Section Material	Concrete		Span	2.50 ft
Section Size	30 inch		Rise	2.50 ft
Number Sections	1			

Outlet Control Properties				
Outlet Control HW Elev.	487.77 ft		Upstream Velocity Head	0.63 ft
Ke	0.50		Entrance Loss	0.31 ft

Inlet Control Properties				
Inlet Control HW Elev.	487.52 ft		Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall		Area Full	4.9 ft^2
K	0.00980		HDS 5 Chart	1
M	2.00000		HDS 5 Scale	1
C	0.03980		Equation Form	1
Y	0.67000			

Culvert Designer/Analyzer Report
Culvert 2

Analysis Component			
Storm Event	Check	Discharge	25.60 cfs

Q_{25}

Peak Discharge Method: User-Specified			
Design Discharge	19.60 cfs	Check Discharge	25.60 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Check Storm.			
Discharge	25.60 cfs	Bottom Elevation	475.14 ft
Depth	1.04 ft	Velocity	8.24 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-30 inch Circular	25.60 cfs	488.22 ft	17.80 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 2

Component:Culvert-1

Culvert Summary				
Computed Headwater Elev	488.22 ft		Discharge	25.60 cfs
Inlet Control HW Elev.	488.01 ft		Tailwater Elevation	476.18 ft
Outlet Control HW Elev.	488.22 ft		Control Type	Entrance Control
Headwater Depth/Height	1.16			

Grades				
Upstream Invert	485.32 ft		Downstream Invert	475.14 ft
Length	152.00 ft		Constructed Slope	0.066974 ft/ft

Hydraulic Profile				
Profile	S2		Depth, Downstream	0.84 ft
Slope Type	Steep		Normal Depth	0.84 ft
Flow Regime	Supercritical		Critical Depth	1.72 ft
Velocity Downstream	17.80 ft/s		Critical Slope	0.005777 ft/ft

Section				
Section Shape	Circular		Mannings Coefficient	0.013
Section Material	Concrete		Span	2.50 ft
Section Size	30 inch		Rise	2.50 ft
Number Sections	1			

Outlet Control Properties				
Outlet Control HW Elev.	488.22 ft		Upstream Velocity Head	0.78 ft
Ke	0.50		Entrance Loss	0.39 ft

Inlet Control Properties				
Inlet Control HW Elev.	488.01 ft		Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall		Area Full	4.9 ft^2
K	0.00980		HDS 5 Chart	1
M	2.00000		HDS 5 Scale	1
C	0.03980		Equation Form	1
Y	0.67000			

Culvert Designer/Analyzer Report
Culvert 3

Analysis Component			
Storm Event	Design	Discharge	215.70 cfs

Q5

Peak Discharge Method: User-Specified			
Design Discharge	215.70 cfs	Check Discharge	291.69 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Design Storm.			
Discharge	215.70 cfs	Bottom Elevation	479.89 ft
Depth	2.28 ft	Velocity	15.78 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-66 inch Circular	215.70 cfs	488.90 ft	15.25 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 3

Component:Culvert-1

Culvert Summary			
Computed Headwater Elev:	488.90 ft	Discharge	215.70 cfs
Inlet Control HW Elev.	488.74 ft	Tailwater Elevation	482.17 ft
Outlet Control HW Elev.	488.90 ft	Control Type	Entrance Control
Headwater Depth/Height	1.29		

Grades			
Upstream Invert	481.80 ft	Downstream Invert	479.89 ft
Length	145.00 ft	Constructed Slope	0.013172 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	3.16 ft
Slope Type	Steep	Normal Depth	2.94 ft
Flow Regime	Supercritical	Critical Depth	4.11 ft
Velocity Downstream	15.25 ft/s	Critical Slope	0.005001 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	5.50 ft
Section Size	66 inch	Rise	5.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	488.90 ft	Upstream Velocity Head	1.99 ft
Ke	0.50	Entrance Loss	1.00 ft

Inlet Control Properties			
Inlet Control HW Elev.	488.74 ft	Flow Control	Transition
Inlet Type	Square edge w/headwall	Area Full	23.8 ft^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Designer/Analyzer Report
Culvert 3

Analysis Component			
Storm Event	Check	Discharge	291.69 cfs

Q_{25}

Peak Discharge Method: User-Specified			
Design Discharge	215.70 cfs	Check Discharge	291.69 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Check Storm.			
Discharge	291.69 cfs	Bottom Elevation	479.89 ft
Depth	2.84 ft	Velocity	17.09 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-66 inch Circular	291.69 cfs	491.45 ft	16.49 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 3

Component:Culvert-1

Culvert Summary				
Computed Headwater Elev:	491.45 ft		Discharge	291.69 cfs
Inlet Control HW Elev.	491.45 ft		Tailwater Elevation	482.73 ft
Outlet Control HW Elev.	490.74 ft		Control Type	Inlet Control
Headwater Depth/Height	1.75			

Grades				
Upstream Invert	481.80 ft		Downstream Invert	479.89 ft
Length	145.00 ft		Constructed Slope	0.013172 ft/ft

Hydraulic Profile				
Profile	S2		Depth, Downstream	3.83 ft
Slope Type	Steep		Normal Depth	3.58 ft
Flow Regime	Supercritical		Critical Depth	4.71 ft
Velocity Downstream	16.49 ft/s		Critical Slope	0.007022 ft/ft

Section				
Section Shape	Circular		Mannings Coefficient	0.013
Section Material	Concrete		Span	5.50 ft
Section Size	66 inch		Rise	5.50 ft
Number Sections	1			

Outlet Control Properties				
Outlet Control HW Elev.	490.74 ft		Upstream Velocity Head	2.81 ft
Ke	0.50		Entrance Loss	1.41 ft

Inlet Control Properties				
Inlet Control HW Elev.	491.45 ft		Flow Control	Submerged
Inlet Type	Square edge w/headwall		Area Full	23.8 ft^2
K	0.00980		HDS 5 Chart	1
M	2.00000		HDS 5 Scale	1
C	0.03980		Equation Form	1
Y	0.67000			

Culvert Designer/Analyzer Report
Culvert 4

Analysis Component			
Storm Event	Design	Discharge	41.90 cfs

Peak Discharge Method: User-Specified			
Design Discharge	41.90 cfs	Check Discharge	66.10 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Design Storm.			
Discharge	41.90 cfs	Bottom Elevation	538.00 ft
Depth	0.74 ft	Velocity	9.40 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-4 x 3 ft Box	41.90 cfs	542.41 ft	9.22 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 4

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev:	542.41	ft	Discharge	41.90	cfs
Inlet Control HW Elev.	542.37	ft	Tailwater Elevation	538.74	ft
Outlet Control HW Elev.	542.41	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.80				

Grades					
Upstream Invert	540.00	ft	Downstream Invert	538.00	ft
Length	200.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	1.14	ft
Slope Type	Steep		Normal Depth	1.14	ft
Flow Regime	Supercritical		Critical Depth	1.51	ft
Velocity Downstream	9.22	ft/s	Critical Slope	0.004541	ft/ft

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	4.00	ft
Section Size	4 x 3 ft		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	542.41	ft	Upstream Velocity Head	0.75	ft
Ke	0.20		Entrance Loss	0.15	ft

Inlet Control Properties					
Inlet Control HW Elev.	542.37	ft	Flow Control	Unsubmerged	
Inlet Type	90° headwall w 45° bevels		Area Full	12.0	ft^2
K	0.49500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	2	
C	0.03140		Equation Form	2	
Y	0.82000				

Culvert Designer/Analyzer Report
Culvert 4

Analysis Component			
Storm Event	Check	Discharge	66.10 cfs

Peak Discharge Method: User-Specified			
Design Discharge	41.90 cfs	Check Discharge	66.10 cfs

Tailwater properties: Rectangular Channel

Tailwater conditions for Check Storm.			
Discharge	66.10 cfs	Bottom Elevation	538.00 ft
Depth	1.00 ft	Velocity	10.98 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-4 x 3 ft Box	66.10 cfs	543.26 ft	10.50 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 4

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev	543.26	ft	Discharge	66.10	cfs
Inlet Control HW Elev.	543.21	ft	Tailwater Elevation	539.00	ft
Outlet Control HW Elev.	543.26	ft	Control Type	Entrance Control	
Headwater Depth/Height	1.09				

Grades					
Upstream Invert	540.00	ft	Downstream Invert	538.00	ft
Length	200.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	1.57	ft
Slope Type	Steep		Normal Depth	1.57	ft
Flow Regime	Supercritical		Critical Depth	2.04	ft
Velocity Downstream	10.50	ft/s	Critical Slope	0.004958	ft/ft

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	4.00	ft
Section Size	4 x 3 ft		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	543.26	ft	Upstream Velocity Head	1.02	ft
Ke	0.20		Entrance Loss	0.20	ft

Inlet Control Properties					
Inlet Control HW Elev.	543.21	ft	Flow Control	Unsubmerged	
Inlet Type	90° headwall w 45° bevels		Area Full	12.0	ft^2
K	0.49500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	2	
C	0.03140		Equation Form	2	
Y	0.82000				

Culvert Designer/Analyzer Report
Culvert 5

Analysis Component			
Storm Event	Design	Discharge	11.00 cfs

Peak Discharge Method: User-Specified			
Design Discharge	11.00 cfs	Check Discharge	14.90 cfs

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	599.00 ft

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-24 inch Circular	11.00 cfs	601.30 ft	1.75 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 5

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev:	601.30	ft	Discharge	11.00	cfs
Inlet Control HW Elev.	601.08	ft	Tailwater Elevation	599.00	ft
Outlet Control HW Elev.	601.30	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.65				

Grades					
Upstream Invert	600.00	ft	Downstream Invert	592.00	ft
Length	90.00	ft	Constructed Slope	0.088889	ft/ft

Hydraulic Profile					
Profile	CompositePressureProfileS1S2		Depth, Downstream	7.00	ft
Slope Type	N/A		Normal Depth	0.39	ft
Flow Regime	N/A		Critical Depth	0.83	ft
Velocity Downstream	1.75	ft/s	Critical Slope	0.004594	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	601.30	ft	Upstream Velocity Head	0.31	ft
Ke	0.50		Entrance Loss	0.16	ft

Inlet Control Properties					
Inlet Control HW Elev.	601.08	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	6.3	ft^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Designer/Analyzer Report
Culvert 5

Analysis Component			
Storm Event	Check	Discharge	14.90 cfs

Peak Discharge Method: User-Specified			
Design Discharge	11.00 cfs	Check Discharge	14.90 cfs

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	599.00 ft

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-24 inch Circular	14.90 cfs	601.54 ft	2.37 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 5

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev:	601.54	ft	Discharge	14.90	cfs
Inlet Control HW Elev.	601.31	ft	Tailwater Elevation	599.00	ft
Outlet Control HW Elev.	601.54	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.77				

Grades					
Upstream Invert	600.00	ft	Downstream Invert	592.00	ft
Length	90.00	ft	Constructed Slope	0.088889	ft/ft

Hydraulic Profile					
Profile	CompositePressureProfileS1S2		Depth, Downstream	7.00	ft
Slope Type	N/A		Normal Depth	0.45	ft
Flow Regime	N/A		Critical Depth	0.97	ft
Velocity Downstream	2.37	ft/s	Critical Slope	0.004812	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	601.54	ft	Upstream Velocity Head	0.38	ft
Ke	0.50		Entrance Loss	0.19	ft

Inlet Control Properties					
Inlet Control HW Elev.	601.31	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	6.3	ft^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Designer/Analyzer Report
Culvert 6

Analysis Component			
Storm Event	Design	Discharge	2.59 cfs

Peak Discharge Method: User-Specified			
Design Discharge	2.59 cfs	Check Discharge	3.51 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	2.59 cfs	Bottom Elevation	521.00 ft
Depth	0.22 ft	Velocity	7.25 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-42 inch Circular	2.59 cfs	530.73 ft	7.84 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 6

Component:Culvert-1

Culvert Summary			
Computed Headwater Elev:	530.73 ft	Discharge	2.59 cfs
Inlet Control HW Elev.	530.56 ft	Tailwater Elevation	521.22 ft
Outlet Control HW Elev.	530.73 ft	Control Type	Entrance Control
Headwater Depth/Height	0.21		

Grades			
Upstream Invert	530.00 ft	Downstream Invert	521.00 ft
Length	180.00 ft	Constructed Slope	0.050000 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.26 ft
Slope Type	Steep	Normal Depth	0.26 ft
Flow Regime	Supercritical	Critical Depth	0.48 ft
Velocity Downstream	7.84 ft/s	Critical Slope	0.004061 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.50 ft
Section Size	42 inch	Rise	3.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	530.73 ft	Upstream Velocity Head	0.17 ft
Ke	0.50	Entrance Loss	0.08 ft

Inlet Control Properties			
Inlet Control HW Elev.	530.56 ft	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	9.6 ft^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Designer/Analyzer Report
Culvert 6

Analysis Component			
Storm Event	Check	Discharge	3.51 cfs

Peak Discharge Method: User-Specified			
Design Discharge	2.59 cfs	Check Discharge	3.51 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Check Storm.			
Discharge	3.51 cfs	Bottom Elevation	521.00 ft
Depth	0.25 ft	Velocity	7.88 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-42 inch Circular	3.51 cfs	530.85 ft	8.59 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 6

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev	530.85	ft	Discharge	3.51	cfs
Inlet Control HW Elev.	530.67	ft	Tailwater Elevation	521.25	ft
Outlet Control HW Elev.	530.85	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.24				

Grades					
Upstream Invert	530.00	ft	Downstream Invert	521.00	ft
Length	180.00	ft	Constructed Slope	0.050000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.30	ft
Slope Type	Steep		Normal Depth	0.30	ft
Flow Regime	Supercritical		Critical Depth	0.56	ft
Velocity Downstream	8.59	ft/s	Critical Slope	0.003940	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.50	ft
Section Size	42 inch		Rise	3.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	530.85	ft	Upstream Velocity Head	0.19	ft
Ke	0.50		Entrance Loss	0.10	ft

Inlet Control Properties					
Inlet Control HW Elev.	530.67	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	9.6	ft^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Designer/Analyzer Report
Culvert 7

Analysis Component			
Storm Event	Design	Discharge	7.92 cfs

Peak Discharge Method: User-Specified			
Design Discharge	7.92 cfs	Check Discharge	10.72 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	7.92 cfs	Bottom Elevation	505.00 ft
Depth	0.38 ft	Velocity	9.82 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-42 inch Circular	7.92 cfs	507.30 ft	7.03 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 7

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev	507.30	ft	Discharge	7.92	cfs
Inlet Control HW Elev.	507.13	ft	Tailwater Elevation	505.38	ft
Outlet Control HW Elev.	507.30	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.37				

Grades					
Upstream Invert	506.00	ft	Downstream Invert	505.00	ft
Length	70.00	ft	Constructed Slope	0.014286	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.61	ft
Slope Type	Steep		Normal Depth	0.61	ft
Flow Regime	Supercritical		Critical Depth	0.85	ft
Velocity Downstream	7.03	ft/s	Critical Slope	0.003729	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.50	ft
Section Size	42 inch		Rise	3.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	507.30	ft	Upstream Velocity Head	0.30	ft
Ke	0.50		Entrance Loss	0.15	ft

Inlet Control Properties					
Inlet Control HW Elev.	507.13	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	9.6	ft^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Designer/Analyzer Report
Culvert 7

Analysis Component			
Storm Event	Check	Discharge	10.72 cfs

Peak Discharge Method: User-Specified			
Design Discharge	7.92 cfs	Check Discharge	10.72 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Check Storm.			
Discharge	10.72 cfs	Bottom Elevation	505.00 ft
Depth	0.44 ft	Velocity	10.63 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-42 inch Circular	10.72 cfs	507.52 ft	7.58 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
Culvert 7

Component:Culvert-1

Culvert Summary					
Computed Headwater Elev	507.52	ft	Discharge	10.72	cfs
Inlet Control HW Elev.	507.33	ft	Tailwater Elevation	505.44	ft
Outlet Control HW Elev.	507.52	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.44				

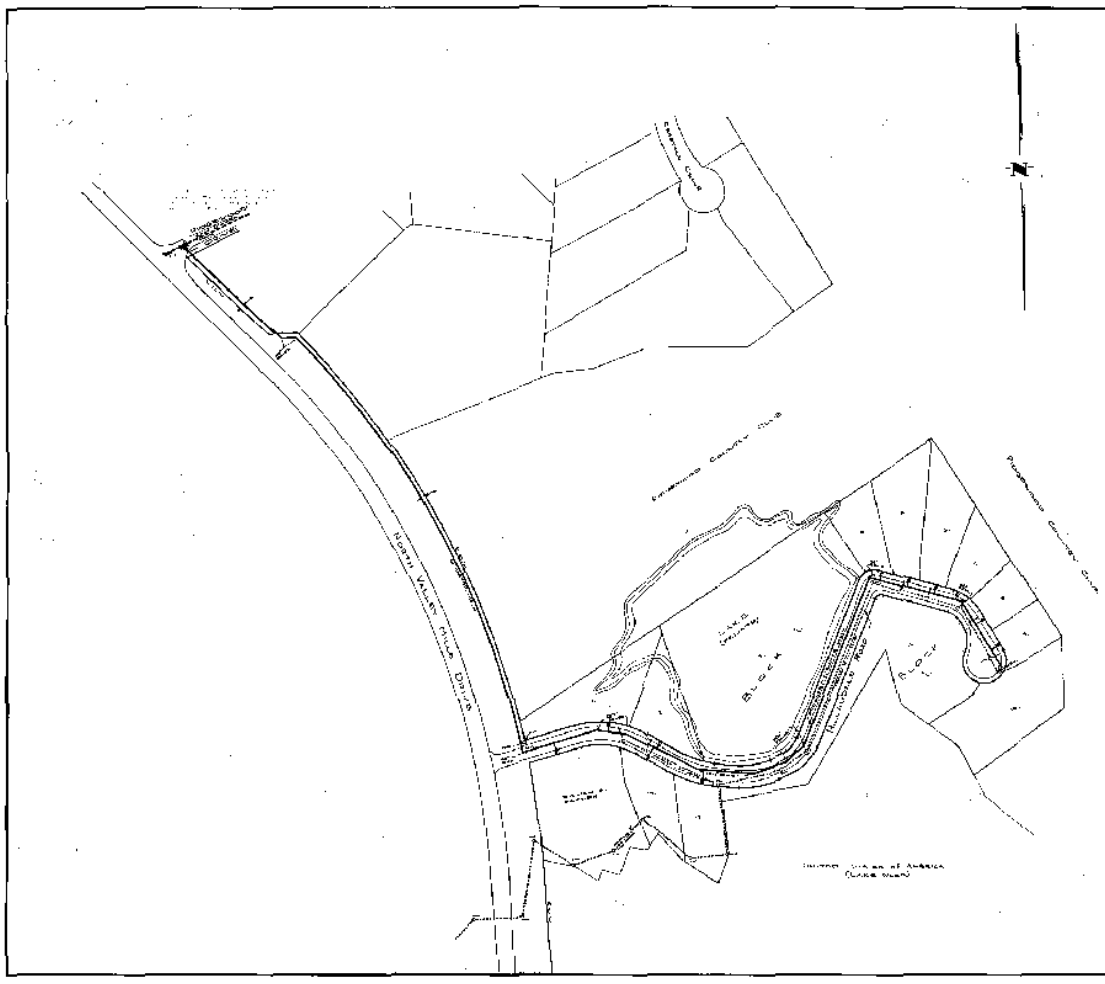
Grades					
Upstream Invert	506.00	ft	Downstream Invert	505.00	ft
Length	70.00	ft	Constructed Slope	0.014286	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.72	ft
Slope Type	Steep		Normal Depth	0.71	ft
Flow Regime	Supercritical		Critical Depth	0.99	ft
Velocity Downstream	7.58	ft/s	Critical Slope	0.003700	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.50	ft
Section Size	42 inch		Rise	3.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	507.52	ft	Upstream Velocity Head	0.36	ft
Ke	0.50		Entrance Loss	0.18	ft

Inlet Control Properties					
Inlet Control HW Elev.	507.33	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	9.6	ft^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				



LEGEND

- ... OF WATER MAIN
- ... FIRE HYDRANT WITH 6" GATE VALVE
- ... 1" SERVICE TAP WITH VERTICAL BOX
- 6" GATE VALVE

THE PROPOSED WATER MAIN SHALL BE LAID AT A DEPTH HAVING NOT LESS THAN 6'6" GRATE COVER TOP OF MAIN

THE CONTRACTOR SHALL CHECK PROPOSED SANITARY SEWER PLAN FOR POSSIBLE CONFLICTS WITH PROPOSED MAIN AND TYPE SERVICE LOCATIONS SHOWN.

THE CONTRACTOR SHALL ALSO CHECK AREA FOR CONFLICTS WITH EXISTING UTILITIES AND PROVIDE THE WORK FOR ANY SUCH PAID CONFLICTS.

THE PROPOSED WATER MAIN SHALL BE LAID NO CLOSER THAN 7'-0" TO THE SANITARY SEWER MAIN.

AS-BUILTS
11-79

HILLAHEALE ADDITION WATER LINE PLAN
UKAN - RODEN & COMPANY CONSULTING ENGINEERS WACO, TEXAS
SCALE 1" = 100'
DESIGNED TRACED APPROVED PROJECT NO. DATE FEBRUARY 4, 1978
SHEET 1 OF 1 SHEETS

W-333