Farnsworth GROUP
5613 DTC Parkway, Suite 1100
Greenwood Village, CO 80111

Lot 4A-1, Heritage Hills Fil. No. 1-F, 2nd Amendment Phase III Drainage Report

Project Address:

9550 Heritage Hills Circle
Lone Tree, CO

Developer:

Chase Bank
2620 E. Camelback Rd.
Phoenix, AZ 85016

Case Number:

Submitted by:

Jay M. Newell, PE
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April 29, 2024

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CERTIFICATION

This report (and plan) for the Phase III drainage design of Lot 4A-1, Heritage Hills Filing No. 1-F, 2nd Amendment, was prepared by me (or under my direct supervision) in accordance with the applicable provisions of the City of Lone Tree Storm Drainage Design and Technical Criteria for the developers thereof. I understand that the City of Lone Tree does not and will not assume liability for drainage and erosion control facilities designed by others.

5 / 14 / 24

SIGNATURE: _____

Registered Professional Engineer
State of Colorado No. 35219

Chase Bank hereby certifies that the drainage facilities for Lot 4A-1, Heritage Hills Filing No. 1-F, 2nd Amendment, shall be constructed according to the design presented in this report. I understand that the City of Lone Tree does not and will not assume liability for the drainage facilities designed and/or certified by my engineer and that the City of Lone Tree reviews drainage plans pursuant to Lone Tree Municipal Code, Chapter 15, Article 1; but cannot, on behalf of Chase Bank, guarantee that final drainage design review will absolve Chase Bank and/or their successors and/or assigns of future liability for improper design. I further understand that approval of the Site Improvement Plan and/or Final Plat does not imply approval of my engineer's drainage design.

_____

Name of Developer

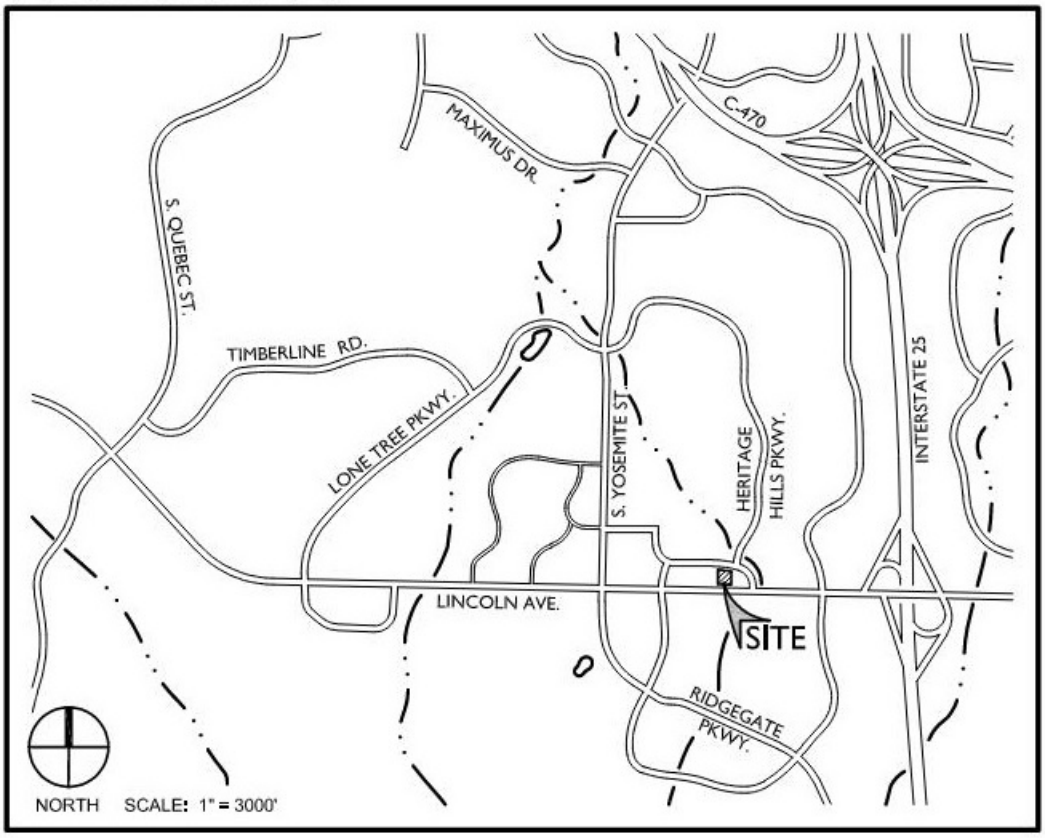
_____

Authorized Signature

II. GENERAL LOCATION AND DESCRIPTION

A. SITE LOCATION

1. SITE VICINITY MAP



2. TOWNSHIP, RANGE, SECTION, AND ¼ SECTION

The project site is located in the Southwest quarter of Section 10, Township 6 South, Range 67 West of the 6th Principal Meridian, in the City of Lone Tree, County of Douglas, State of Colorado.

3. EXISTING AND PROPOSED STREETS

The project site is bound by Heritage Hills Circle to the north, and Lincoln Avenue to the south; approximately 4/10 of a mile east of the intersection of Lincoln Avenue and South Yosemite Street.

4. SURROUNDING DEVELOPMENTS

Lone Tree Elementary Magnet School property lies north of the site immediately north of Heritage Hills Circle. Commercial development consisting of a Bank of the West on Lot 5 of the subdivision is immediately east of the project site and shares a common private drive with the project site. Immediately west of the site is a City of Lone Tree operated pedestrian overpass ramp for the Willow Creek Trail system. West of this structure lies the Lincoln Hills commercial development including Chipolte, Carmines Pizza & Pasta, and Vibe Foods restaurants. South, across Lincoln Avenue, is open space operated by the City of Lone Tree for the continuation of the Willow Creek Trail system and drainage facilities.

B. DESCRIPTION OF PROPERTY

1. AREA

The project site (Lot 4A-1, Heritage Hills Filing No. 1-F, 2nd Amendment) is 1.398 acres.

2. GROUND COVER, TOPOGRAPHY AND SLOPES

Based on review of aerial and other imagery available on the internet and site visit(s), the project site appears to be covered by a combination of grasses, weeds, and compacted dirt in addition to the existing shared asphalt common private drive along the north and east sides of the lot. The project site generally slopes from the southwest to the northeast; at a 3:1 slope in the far southwest corner transitioning to a 4.0% slope across the majority of the property. The asphalt drives both slope at approximately 2.0% toward a common low point near the northeast corner of the project site.

3. NRCS SOILS

The United States Department of Agriculture (**USDA**) Natural Resources Conservation Service (**NRCS**) Web Soil Survey indicates site soils are comprised of Newlin-Santana complex, 5 to 20 percent slopes (NsE) and Renohill-Buick complex, 5 to 25 percent slopes (RmE), rated Hydrologic Soil Group B and D respectively.

4. MAJOR AND MINOR DRAINAGEWAYS

As described on the Mile High Flood District's (**MHFD**) online General Data Viewer, the project site lies within the Willow Creek Watershed, which is tributary to Little Dry Creek, itself a tributary of the South Platte River.

5. FLOODPLAINS

The Federal Emergency Management Agency (**FEMA**), *Flood Insurance Rate Map* (**FIRM**) *for Douglas County, Colorado and Incorporated Areas*, Map Number 08035C0042G, revised March 16, 2016, indicates the project site to be in Zone X (unshaded); "Areas determined to be outside the 0.2% annual chance floodplain."

6. EXISTING IRRIGATION DITCHES

There are no apparent irrigation canals nor ditches within or adjacent to the project site.

7. SIGNIFICANT GEOLOGIC FEATURES

There are no apparent significant geologic features within or adjacent to the project site.

8. PROPOSED LAND USE

The project site is intended to be developed as an approximately 3,300 square foot commercial bank with drive-through service and a parking area typical of similar developments within the Front Range.

III. DRAINAGE BASINS AND SUB-BASINS

A. MAJOR DRAINAGE BASINS

1. ON-SITE AND OFF-SITE MAJOR DRAINAGE BASIN CHARACTERISTICS

The Willow Creek Watershed is characteristic of similar basins within the developed portions of Douglas and Arapahoe counties. Runoff is generally conveyed from the south to the north within Willow Creek and its minor tributaries. The City of Lone Tree Municipal Separate Storm Sewer System (**MS4**) within the basin is understood to capture and convey runoff to the same.

2. EXISTING AND PROPOSED LAND USES

Review of aerial imagery available on the internet suggests the approximately 2,600 acre Willow Creek Watershed is comprised of residential development across much of the basin, interspersed with open space and golf course; commercial development in the northern, eastern, and southeastern portions; and additional open space at the basin's southern end. Proposed development is assumed to be similar, in accordance with the zoning regulations and designations of the City of Lone Tree, and surrounding jurisdictions.

3. DISCUSSION OF DRAINAGEWAY STUDIES

The most recent study found within the MHFD archives is the *Willow Creek, Little Dry Creek, and Greenwood Gulch Outfall Systems Planning Study,* prepared by CH2M HILL and dated February 2010 (**OSP**). The OSP provides further description to that above of the major basin's characteristics, flow patterns and paths, and existing and proposed land uses. In addition, the OSP notes that, "For the Willow Creek watershed, no previous hydrologic study has been found that is comparable in size and scope with the hydrology developed in…" the OSP; and further that, "Most studies have been performed for the entire Little Dry Creek Watershed, which includes Willow Creek as a tributary. However, no detailed analysis of the Willow Creek watershed has been published to date."

The OSP includes an analysis of "Problem Areas" within its study limits. For the reach of Willow Creek from Lincoln Avenue to Yosemite Street in the vicinity of the project site, although not immediately adject to it, the analysis states "Failing drop structure downstream of Heritage Hills Parkway," and "Channel bank erosion at bends throughout reach" as the prevailing problems. The OSP's "Recommended Alternative" for addressing these problems includes stabilizing the outfall located approximately 2,400 feet downstream of the creek's crossing under Heritage Hills Parkway; stabilizing the banks approximately 2,100 feet downstream and approximately 800 feet downstream of the same crossing; and replacing the failing drop structure immediately downstream of the same crossing.

In addition, the OSP generally recommends that jurisdictions having review or maintenance responsibility:

- "…take steps to stabilize all major waterways…"
- "…rehabilitate existing degraded reaches of the waterways…"
- "…aggressively control erosion and sediment transport during construction activities…"
- "…require new land development…to provide, to the maximum extent practicable, runoff volume control practices (i.e., minimize directly connected impervious areas and employ infiltrating BMPs) whenever site conditions permit…"
- "…require new land development…to provide a Water Quality Capture Volume (**WQCV**)…"
- "…take steps to limit further increases in stormwater runoff through the use of additional on-site detention, infiltrating BMPs, Full Spectrum detention facilities, and WQCV BMPs…""…whenever land use changes result in impervious ratios that exceed the projections identified in this [OSP]."

The OSP includes the project site within its 115 acre Basin 11; described as having an imperviousness of 57% (more specifically Basin W11; imperviousness = 57.3%), based on the assigned land use imperviousness values included in the OSP's Table 2-1.

4. DISCUSSION OF EXISTING CHANNEL CONDITIONS

Notwithstanding the recommendations of the OSP included herein, the proposed development is intended to be in compliance with the City of Lone Tree criteria and with pertinent drainage studies listed herein. Compliance with these design criteria is understood to meet the need for any channel improvements and associated impacts to the proposed development noted herein above.

5. DISCUSSION OF OFF-SITE FLOW

Ridgelines along the Lincoln Avenue right-of-way (**R.O.W.**) south of the project site, and along the centerline of the shared common private drive immediately east of the project site preclude off-site runoff impacting the project site from these adjacent properties. The Heritage Hills Circle R.O.W. immediately north of the project site conveys flow away from the project site, precluding off-site runoff from this direction as well. The existing pedestrian overpass ramp immediately west of the project site effectively eliminates off-site runoff from this direction except for downspouts serving the ramp which discharge to the project site. The proposed drainage design is intended to minimize developed flow off-site by capturing and conveying all on-site runoff to either the proposed stormwater management facility or to the existing inlet and subsequent storm sewer system located at the overall low point near the northeast corner of the project site, both described in more detail below.

B. MINOR DRAINAGE BASINS

1. ON-SITE AND OFF-SITE MINOR DRAINAGE BASIN CHARACTERISTICS

The project site lies more specifically within Heritage Hills Filing No. 1-F; an 8.29 acre area of commercial development bound by Heritage Hills Circle on the north and east, Lincoln Avenue on the south, and the existing bank and Safeway grocery store anchored commercial development near the intersection of Lincoln Avenue and Commons Drive to the west. Runoff is generally conveyed through the Heritage Hills Filing No. 1-F development from south to north and from west to east as surface flow across paved parking and pedestrian areas and their associated landscape areas to adjacent curb and gutter prior to being either captured by private storm sewer systems or discharged directly to Heritage Hills Circle and its associated public storm sewer system. This public system is understood to capture runoff in inlets in the vicinity of the intersection of Heritage Hills Circle and Heritage Hills Parkway prior to being discharged to Willow Creek, immediately north of this intersection and its downstream regional detention facility. Development of the project site is not intended to change these drainage patterns or paths.

2. EXISTING AND PROPOSED LAND USES

All of the Heritage Hills Filing No. 1-F lots are commercially developed except for the subject project site, which is currently vacant.

3. DISCUSSION OF IRRIGATION FACILITIES

There are no apparent irrigation facilities within or adjacent to the project site.

4. DISCUSSION OF OFF-SITE FLOW

A discussion of off-site flow patterns and paths is included in Section III.A.5 herein.

IV. DRAINAGE DESIGN CRITERIA

A. REGULATIONS

1. COUNTY CRITERIA

This report references the Douglas County, *Storm Drainage Design and Technical Criteria Manual* (**CRITERIA**), current edition where applicable and as noted herein, in accordance with the City of Lone Tree's adoption of said manual as the city's criteria.

2. UDFCD MANUAL

This report references the MHFD, *Urban Storm Drainage Criteria Manual, Volumes 1 through 3* (**USDCM**), current editions, where applicable and as noted herein, as referenced by the CRITERIA.

B. DRAINAGE STUDIES, OUTFALL SYSTEMS PLANS, SITE CONSTRAINTS

1. DISCUSS PREVIOUS STUDIES

The *Phase III Drainage Report, Heritage Hills Filing No. 1-F*, prepared by JR Engineering, LTD., dated July 1999 (**JR REPORT**), includes the project site within its limits of design and analysis for the development of the five lots and adjacent R.O.W. within Heritage Hills Filing No. 1-F, including allowance for conveyance of the project site's developed runoff within the public improvements associated with Heritage Hills Circle. The JR REPORT includes the project site generally as its Basin C. The JR REPORT indicates no off-site basins contributing runoff to the project site. Basin C is 2.14 acres with an imperviousness of 95% (based on comparison of the included runoff coefficients – C_5 = 0.87, C_{100} = 0.89 – and the correlating imperviousness reported on Table 3-1 (42) of the report).

2. DISCUSS DRAINAGE STUDIES FOR ADJACENT DEVELOPMENTS

The *Drainage Report and Erosion Control Plan For Commercial Federal Bank*, prepared by Huitt-Zollars, Inc., dated August 27, 2003, (**LOT 5 REPORT**), includes the project site within its limits of design and analysis as an off-site basin for the more specific development of Lot 5 within the Heritage Hills subdivision, including allowance for conveyance of the project site's developed runoff through Lot 5 to downstream public improvements within Heritage Hills Circle. The LOT 5 REPORT includes the project site generally as its Basin E. The LOT 5 REPORT indicates no off-site basins contributing runoff to the project site. Basin E is 1.95 acres with an imperviousness of 95% (as noted within the report: "Note: impervious percentage and runoff coefficients for Basin E are taken from the existing JR Engineering drainage report because the expected future development of this area has not changed from that report.")

3. DISCUSS UDFCD OUTFALL SYSTEMS PLANS

The MHFD OSP, described above, includes the project site within its limits of design and analysis. Detailed discussion of recommendations within the OSP that may affect the project site design are generally included in Section III.A.3 herein.

4. DISCUSS IMPACTS TO STORMWATER MANAGEMENT FACITLIY DESIGN

Site constraints associated with the project site that impact the stormwater management facility design include the location, alignment, depth and capacity of the existing downstream drainage facilities both within Heritage Hills Circle and within Lot 5. The location and elevation(s) of the shared common private drive also constrain proposed grading and therefore the proposed drainage facilities. The location, alignment, depth and size of the existing waterline and sanitary sewer utilities serving the project site and the adjacent property to the east similarly constrain the proposed stormwater management facility design.

C. HYDROLOGY

1. RUNOFF CALCULATION METHOD(S)

The Rational Method is used for calculating runoff.

2. DESIGN STORM RECURRENCE INTERVALS

The minor and major storm recurrence intervals used for sizing stormwater management facilities are the 5-year and the 100-year respectively.

3. DESGIN RAINFALL

Design rainfall within the JR REPORT and within the LOT 5 REPORT is from the CRITERIA, Figures 501 and 502A for Zone I, dated November 1984. Current CRITERIA design rainfall is obtained from its Figure 6-1 and Figure 6-2. The project site lies within Douglas County Rainfall Zone I.

4. DETENTION STORAGE CALCULATION METHOD(S)

As described below, detention storage calculations are not applicable to the drainage design for the project site.

5. DETENTION STORAGE RELEASE RATE CALCULATION METHOD

As described below, detention storage release rate calculations are not applicable to the drainage design for the project site.

D. HYDRAULICS

1. METHODS USED TO DETERMINE CONVEYANCE FACILITY CAPACITIES

Bentley Systems, Incorporated's CONNECT Edition Update 3 version of FlowMaster ® has been used to determine conveyance facility capacities based on the Manning Formula.

2. HYDRAULIC GRADE LINE CALCULATION METHOD

Hydraulic Grade Line calculations are not included in this report.

3. METHODS USED TO CALCULATE WATER SURFACE PROFILE

Water surface profile calculations are not applicable to the drainage design for the project site.

4. DETENTION POND ROUTING

Detention pond routing calculations are not applicable to the drainage design for the project site.

E. WATER QUALITY ENHANCEMENT

1. DISCUSS PROPOSED BEST MANAGEMENT PRACTICES

In accordance with the CRITERIA, permanent post-construction stormwater quality management is required to follow a four-step approach:

- Step 1: Employ Runoff Reduction Practices (Minimizing Directly Connected Impervious Areas (**MDCIA**)) in accordance with the CRITERIA's hierarchy for implementation which prioritizes areas from highest priority to lowest in the following order; (1) parking lots and driveways, (2) other paved areas, (3) roof areas, and (4) other areas identified with potential pollutants.

  The proposed development is designed to mitigate the loss of developable space for future tenant(s) which may locate on the northern, undeveloped, portion of the existing lot. This

constraint limits opportunities for implementation of MDCIA for parking and drives other than conveyance of runoff from these areas to a downstream stormwater management facility which effectively disconnects such impervious areas from downstream facilities. Notwithstanding, the eastern portion of the parking lot's northern bay of stalls is designed without the benefit of standard curb and gutter; thus allowing runoff to sheet flow onto an adjacent landscape area prior to the stormwater management's 4:1 side slopes. Although not technically designed as a MHFD Grass Buffer, and therefore not being factored into a quantifiable Runoff Reduction calculation; the design does decrease the Directly Connected Impervious Area (**DCIA**) and increase the Unconnected Impervious Area (**UIA**) consistent with the principals of ow Impact Development (**LID**). Other paved areas which are disconnected include portions of the proposed walks which convey runoff over adjacent landscaped areas. Runoff from the proposed roof area is generally captured and conveyed in an underground storm sewer system also tributary to the downstream stormwater management facility. This design is typical of similar developments along the Front Range and is intended to avoid the discharge of runoff to areas adjacent to the building which may jeopardize the building's foundation. This design is also intended to avoid the discharge of runoff to areas where icing may endanger pedestrian traffic within the development.

- Step 2: Implement Control Measures (**CM**s) with WQCV with Slow Release. The project site is served by a proposed stormwater management facility which provides the WQCV required in accordance with the CRITERIA's Water Quality Control Measure Selection Requirements. These requirements enumerate four standards available for conformance: (1) Water Quality Capture Volume, (2) Runoff Reduction, (3) Regional WQCV, and (4) Constrained Redevelopment Site. The drainage design for the project site described herein meets the Water Quality Capture Volume standard which requires treatment for the entire new development except for areas which cannot practically drain to a post-construction CM, "…such as driveway access, perimeter sidewalks, or tree lawns…" not to exceed 20% of the site or one acre.

- Step 3: Stabilize Streams. There are no drainageways on or adjacent to the project site. The stabilization of such drainageways is therefore outside the scope of development for the project site.

- Step 4: Implement Site-specific and Other Source Controls. Site activities and operations at any site are difficult to determine with specificity within the limits of a drainage report. Source controls necessary to prevent the potential for illicit discharges are the responsibility of the property owner and/or the owner's tenant(s) in correlation to the activities and operations that occur as the project site is occupied and used. Regardless, based on the projected development of the project site, activities including, but not limited to regular landscape care (mowing, fertilizing, etc.) and trash containment and disposal may impact stormwater quality. These activities should be carried out to minimize the exposure of potential pollutants to stormwater. In addition, trash control should be regularly scheduled and disposal handled in accordance with city regulations.

2. IDENTIFY DESIGN PROCEDURES

Table 14-1 (Selection and Applicability of Standard Control Measures) of the CRITERIA suggests that of the potential CMs suited to providing the required WQCV; neither Extended Detention Basins (**EDB**s), nor Modified Extended Detention Bains (**MEDB**s) are suitable for sites less than 5 acres. Of the remaining CMs (Sand Filter (**SF**) or Bioretention/Rain Garden (**RG**)) available, the drainage design for the project site described herein makes use of a RG that meets the requirements of the CRITERIA and of the USDCM, particularly its Fact Sheet T-3, Bioretention.

V. STORMWATER MANAGEMENT FACILITY DESIGN

A. STORMWATER CONVEYANCE FACILITIES

1. GENERAL CONVEYANCE CONCEPTS

Proposed runoff will be conveyed as surface flow across the site generally from southwest to northeast, collected in curb and gutter, and conveyed to a low point at the northeast corner of the proposed parking lot, from where it will be discharged directly to the proposed stormwater management facility. Rooftop runoff will be collected and conveyed in a storm sewer system to the same stormwater management facility.

2. PROPOSED DRAINAGE PATHS AND PATTERNS

On-site surface runoff will generally flow away from the proposed building toward the perimeter of the site and its drives and parking areas. A portion of the shared common private drive east of the site will remain tributary to the existing inlet already capturing this runoff. The undeveloped northern portion of the project site and the existing shared common private drive to its north will continue to follow their existing drainage patterns.

More specifically:

Basin A consists of the majority of the project site's improvements; including paved parking and pedestrian areas and associated landscaped areas. This basin is designed to convey runoff as surface flow across the paved and landscaped areas to private curb and gutter. The curb and gutter is intended to convey runoff to a recessed curb along the northeast edge of the proposed parking lot from whence it will be discharged to the proposed stormwater management facility.

Basin R consists of the project site's proposed roof area. Runoff is intended to be conveyed by an underground storm sewer system to the proposed stormwater management facility.

Basin O1 consists of off-site areas including undeveloped area reserved for future development (O1a), off-site area within the LOT 5 REPORT's Basin F (O1b) which is not tributary to the project site, and area to be developed as a proposed stormwater management facility serving the project site (O1c). Basin O1a is intended to convey runoff in its historic condition, as surface flow to the adjacent shared common private drive and its associated inlet and storm sewer outfall designed and constructed in conjunction with development of Lot 5 to the east. Basin O1b is intended to convey runoff in its historic condition, as surface flow to the Heritage Hills Circle R.O.W. and the City of Lone Tree MS4 which serves this public street. Basin O1c is intended to convey runoff as surface flow across landscaped areas directly to the stormwater management facility.

Basin O2 consists of off-site area currently paved to serve as a shared common private drive serving the project site and Lot 5 to the east. Runoff is intended to be conveyed in its historic manner, across the paved surface(s) to adjacent curb and gutter prior to being captured by the associated inlet and storm sewer outfall designed and constructed in conjunction with development of Lot 5 to the east.

Basin O3 consists of off-site landscaped areas along the west perimeter of the project site associated with the development of the existing, adjacent, pedestrian overpass ramp. Runoff is intended to be conveyed as surface flow across landscaping to landscaping and/or pavement to be developed in association with the project site. Although such off-site runoff will generally follow the on-site drainage path(s) to the proposed stormwater management facility, its contribution is not accounted for in the WQCV, nor in the proposed facility outfall. Rather, it will exit the facility through the facility's overflow

weir to the private drive within Basins O1a and O2 and the existing inlet and storm sewer system serving these basins as described above. Basin O3a lies along the west side of the project site's proposed improvements. Basin O3b is immediately upstream of the stormwater management facility. Basin O3c is immediately upstream of Basin O1a and is therefore not tributary to the stormwater management facility.

Basin O4 consists of off-site area comprised of the existing pedestrian overpass ramp immediately west of the site. Its area makes up the remainder of the LOT 5 REPORT's Basin E. Partial contribution to the site is represented by Basins $O4_1$ and $O4_2$, each associated with a corresponding downspout serving the pedestrian overpass ramp.

3. STORM SEWER DESIGN

Basin R is conveyed in the roof drain collection storm sewer system from the building perimeter, north to the stormwater management facility at Design Point 3 (Q_5 = 0.29 cfs; Q_{100} = 0.57 cfs).

4. STORM SEWER OUTFALL

The roof drain collection system discharges to the stormwater management facility through a concrete pipe outlet.

5. DISCUSS RUNOFF CONVEYANCE FROM OUTFALL(S) TO NEAREST MAJOR DRAINAGEWAY

Developed runoff will be conveyed to the nearest major drainageway by way of the stormwater management facility and its outfall(s) described in Section V.C.2 herein.

6. DISCUSS OPEN CHANNEL DESIGN

The on-site sidewalk chase designed in association with the pedestrian access from the project site to the Willow Creek Trial System and associated pedestrian overpass ramp has also been sized to convey a portion of Basin A's and contributing off-site basins' runoff (Q_5 = 0.89 cfs; Q_{100} = 2.10 cfs).

7. ALLOWABLE STREET CAPACITIES

Allowable street capacities are not applicable to the drainage design for the project site.

8. MAINTENANCE AND EASEMENTS

The proposed storm sewer is intended to be privately operated and maintained in accordance with local practices. Easements for this private system are not necessary.

9. DISCUSS FACILITIES NEEDED OFF-SITE FOR CONVEYANCE OF FLOWS TO THE MAJOR DRAINAGEWAY

Facilities other than those described in Section V.C.2 herein and facilities that currently exist to convey runoff to the major drainageway are not applicable to the drainage design for the project site.

B. STORMWATER STORAGE FACILITIES

1. DETENTION POND DESIGN

As indicated in both the JR REPORT and the LOT 5 REPORT, detention for the project site is provided off-site, downstream in existing regional detention facilities.

2. POND OUTFALL

A discussion of pond outfall(s) is not applicable to the drainage design for the project site.

3. CONVEYANCE FROM POND OUTFALL AND EMERGENCY SPILLWAY TO NEAREST MAJOR DRAINAGEWAY

A discussion of conveyance from pond(s) to the major drainageway is not applicable to the drainage design for the project site.

4. MAINTENANCE AND EASEMENTS

A discussion of maintenance and associated easements for pond(s) is not applicable to the drainage design for the project site.

C. WATER QUALITY ENHANCEMENT BEST MANAGEMENT PRACTICES

1. STRUCTURAL WATER QUALITY BEST MANAGEMENT PRACTICES

The stormwater management facility for the project site has been designed as a RG bioretention facility. The facility has been designed to treat runoff from Basins A, R, and O1c (area = 34,027 sf; %imp = 57). Runoff from Basins O1a, O1b, O2, O3c and a portion of O4 ($O4_2$) is not tributary to the facility. The city's four-step approach to stormwater quality management will ultimately need to be addressed for development of Basin O1a, either through modification of the proposed RG bioretention facility described herein, or through the design and construction of separate facilities to be constructed at the time of Basin O1a's development. Although runoff from Basins O3a, O3b, and a portion of O4 ($O4_1$) is tributary to the facility; this offsite runoff is allowed to bypass the facility primarily through the overflow weir to its historic conveyance within the shared common private drive (combined with Basins A, R and O1c emergency overflow, Q_5 = 1.59 cfs; Q_{100} = 4.11 cfs). The facility is sized in accordance with applicable criteria to provide more than the minimum required 514 cubic-foot WQCV within 6-inches of depth over a filter area of 1,442 square-feet. The facility is designed as a "Partial-Infiltration Section" and therefore includes an underdrain with orifice control for a 12-hour drain time while allowing, but not relying on, incidental infiltration. The facility's outlet structure captures and conveys up to 100-year event runoff from on-site tributary basins while passing off-site tributary runoff and excess emergency flows through an overflow weir directly to the shared common private drive.

2. DISCUSS RUNOFF CONVEYANCE FORM POND OUTFALL(S) TO THE NEAREST MAJOR DRAINAGEWAY

The facility's outlet structure outfall pipe will convey runoff (Q_5 = 1.37 cfs; Q_{100} = 3.59 cfs) to an existing inlet, designed and constructed with the development of Lot 5 to the east, serving the project site and the common private drive shared with Lot 5. The outfall will directly connect to the existing inlet vault. Off-site runoff tributary to the proposed stormwater management facility (Q_5 = 0.22 cfs; Q_{100} = 0.53 cfs) will generally bypass the facility through its overflow weir to the shared common private drive where it will combine with other off-site runoff (Q_5 = 3.97 cfs; Q_{100} = 8.53 cfs) prior to being conveyed to and captured by the aforementioned existing inlet (LOT 5 REPORT, Basin E, 15' Type R inlet; capacity = 15.61 cfs). This inlet's outfall (LOT 5 REPORT, Lateral C-1; capacity 15.61 cfs) will continue to convey project site runoff to the Heritage Hills Circle public storm sewer system, Willow Creek, and the existing downstream regional detention pond beyond in its existing manner.

3. OPERATION, MAINTENANCE AND EASEMENTS

The facility is intended to be privately operated and maintained in accordance with local practices. Easements have been proposed with the development documents for the project site to allow access to the stormwater management facility, and its outlet structure, overflow weir, and outfall pipe.

D. FLOODPLAIN MODIFICATION

1. PROPOSED FLOODPLAIN MODIFICATIONS

Floodplain modifications are not applicable to the drainage design for the project site.

2. SOURCE FO FLOODPLAIN INFORMATION

The source of floodplain information is included in Section II.B.5 above.

3. DETAILS OF FLOODPLAIN MODIFICATION

Floodplain modification details are not applicable to the drainage design for the project site.

4. CLOMR AND LOMR REQUIREMENTS

Neither CLOMR nor LOMR requirements are applicable to the drainage design for the project site.

5. COUNTY FLOODPLAIN DEVELOPEMT REGULATIONS

County floodplain regulations are not applicable to the drainage design for the project site.

E. ADDITIONAL PERMITTING REQUIREMENTS

1. SECTION 404 OF THE CLEAN WATER ACT

To the best of Farnsworth Group's knowledge and belief, Section 404 of the Clean Water Act is not applicable to the drainage design for the project site.

2. ENDANGERED SPECIES ACT

To the best of Farnsworth Group's knowledge and belief, the Endangered Species Act is not applicable to the drainage design for the project site.

3. OTHER LOCAL, STATE, OR FEDERAL REQUIREMENTS

The City of Lone Tree requires development of property to comply with its Construction Site Grading, Erosion, and Sediment Control (GESC) Program. Development sites that disturb greater than or equal to 1 acre of land must also comply with the State of Colorado, Department of Public Health and Environment (**CDPHE**), Water Quality Control Division regulated Colorado Discharge Permit System (**CDPS**), specifically for control of construction site stormwater runoff.

F. GENERAL

1. TABLES, FIGURES, CHARTS AND DRAWINGS

All tables, figures, charts and drawings are sourced where they appear herein and are included in the appendices of this report for reference.

VI. CONCLUSIONS

A. COMPLIANCE WITH STANDARDS

1. DOUGLAS COUNTY CRITERIA

The stormwater management design described in this report is intended to be in compliance with applicable portions of the CRITERIA.

2. UDFCD CRITERIA

The stormwater management design described in this report is intended to be in compliance with applicable portions of the USDCM.

3. MASTER PLANS AND UDFCD OUTFALL SYSTEMS PLANS

The stormwater management design described in this report is intended to be in compliance with applicable portions of the OSP.

4. CHERRY CREEK RESERVOIR CONTROL REGUALTION NO. 72

Runoff from the project site is not tributary to Cherry Creek Reservoir.

5. CHATFIELD RESERVOIR CONTROL REGUALTION NO. 73

Runoff from the project site is not tributary to Chatfield Reservoir.

B. VARIANCES

1. PROVISIONS FOR WHICH A VARIANCE WILL BE REQUESTED

Variance requests are not applicable to the drainage design for the project site.

2. JUSTIFICATION

Variance request justifications are not applicable to the drainage design for the project site.

C. DRAINAGE CONCEPT

1. OVERALL EFFECTIVENESS OF STORMWWATER MANAGEMENT DESIGN

The stormwater management design described in this report has been designed to effectively convey the required runoff through the site in accordance with applicable criteria and existing drainage studies.

More specifically, the JR REPORT indicates that the City of Lone Tree MS4 within Heritage Hills Circle, in combination with the Heritage Hills Circle street section, was designed to convey developed runoff from its Basins A, B, C, E and F at its Inlet-1, combining runoff from its Design Points 2, 3 and 4. Additionally, the LOT 5 REPORT indicates that the Lot 5 drainage system was designed to capture and convey developed runoff from its Basins A through F (equivalent to JR REPORT Basins C and E) at its Design Point 6. As the table indicates, the LOT 5 REPORT design results in runoff at Inlet-1 which is less than assumed in the JR REPORT.

TABLE VI.C.1a

REPORT	BASIN	AREA (ac.)	IMP. (%)	C_5	C_{100}	Q_5 (cfs)	Q_{100} (cfs)
JR	C	2.14	95	0.87	0.89	[1]6.24	15.96
JR	E	1.80	95	0.87	0.89	5.30	13.60
	TOTAL	[3]3.94				[1]11.54	29.56
JR	(F	1.36	100	0.88	0.93	3.30	8.69)
	[2]TOTAL					14.84	38.25
LOT 5	A	0.58	48	0.39	0.60	0.85	2.42

LOT 5	B	0.38	56	0.44	0.62	0.73	1.94
LOT 5	C	0.28	66	0.52	0.67	0.64	1.55
LOT 5	D	0.19	61	0.47	0.63	0.43	1.03
LOT 5	E	1.95	95	0.87	0.89	8.31	15.61
LOT 5	F	0.61	1.77	0.16	0.50	0.40	2.16
	TOTAL	[3]3.99				11.36	24.71
JR	(F	1.36	100	0.88	0.93	3.30	8.69)
	[2]TOTAL					14.66	33.40

[1]The LOT 5 REPORT notes that the JR REPORT Q_5 = 6.24 cfs is based on a rainfall intensity of 3.35 in/hr for a reported Tc = 6.5 min. in error; and that the correct intensity for 6.5 min. should be 4.35 in/hr for a resultant Q5 = 8.09 cfs at Design Point 3, and a resultant total of 13.39.
[2]Although the majority of the project site lies within the JR REPORT's Basin C and within the LOT 5 REPORT's Basin E; comparison of runoff at Design Points for common tributary areas is provided to indicate compliance as described in LOT 5 REPORT.
[3]Includes the JR REPORT Basin F contribution as included in the LOT 5 REPORT for comparison.

Table VI.C.1b, herein, compares this report's calculated proposed runoff for the project site to that of the LOT 5 REPORT to confirm compliance with the existing report's assumptions and to confirm capacity within the subsequent downstream improvements.

Table VI.C.1b

REPORT	**BASIN**	**AREA** (ac.)	**IMP** (%)	**C_5**	**C_{100}**	**Q_5** (cfs)	**Q_{100}** (cfs)
LOT 5	E	1.95	95	0.87	0.89	8.31	15.61
PROPOSED	A	0.56	65	0.57	0.75	1.39	3.33
PROPOSED	R	0.08	90	0.77	0.85	0.29	0.57
PROPOSED	O1a	0.61	[1]95	0.87	0.89	2.59	4.81
PROPOSED	O1b	0.00	[2]1.77	0.16	0.50	0.00	0.01
PROPOSED	O1c	0.14	6	0.08	0.51	0.06	0.65
PROPOSED	O2	0.11	[1]95	0.87	0.89	0.47	0.86
PROPOSED	O3a	0.03	2	0.05	0.49	0.01	0.14
PROPOSED	O3b	0.01	2	0.05	0.49	0.00	0.03
PROPOSED	O3c	0.01	2	0.05	0.49	0.00	0.02
PROPOSED	O4	0.40	[1]95	0.87	0.89	[3]0.61	[3]1.13
	TOTAL	1.95	78	0.67	0.80	[4]6.40	[4]14.04

[1]Basin imperviousness assumed for future development to match Basin E of the LOT 5 REPORT (and subsequently of the JR REPORT).

[2]Basin imperviousness assumed for existing development to match Basin F of the LOT 5 REPORT.
[3]Runoff calculated from combining runoff from Basins *O4$_1$* and *O4$_2$*.
[4]Runoff calculated from TOTAL area, runoff coefficient, and an assumed Tc (4.9 min.) and corollary intensity (I_5=4.90 in/hr; I_{100}= 9.00 in/hr) matching the LOT 5 REPORT. Runoff routing calculations in the Appendix indicate total 5-year and total 100-year runoff at design point 11 (tributary to the Lot 5 underground drainage system) = 3.97 cfs and 8.53 cfs respectively (< 6.40 cfs and 14.04 cfs respectively herein and < 8.31 cfs and 15.61 cfs respectively for the LOT 5 REPORT Lateral C-1 at 47.44% full and 71.36% full respectively; and for the LOT 5 REPORT inlet calculation for the existing inlet at Design Point 11).

VII. REFERENCES

1. Web Soil Survey, United States Department of Agriculture, National Resources Conservation Service, http://websoilsurvey.nrcs.usda.gov/app/

2. *Flood Insurance Rate Map for Douglas County, Colorado and Incorporated Areas, Map Number 08035C0042G*, revised March 16, 2016, Federal Emergency Management Agency, https://msc.fema.gov/portal/home.

3. *Willow Creek, Little Dry Creek, and Greenwood Gulch Outfall Systems Planning Study,* CH2M HILL, February 2010.

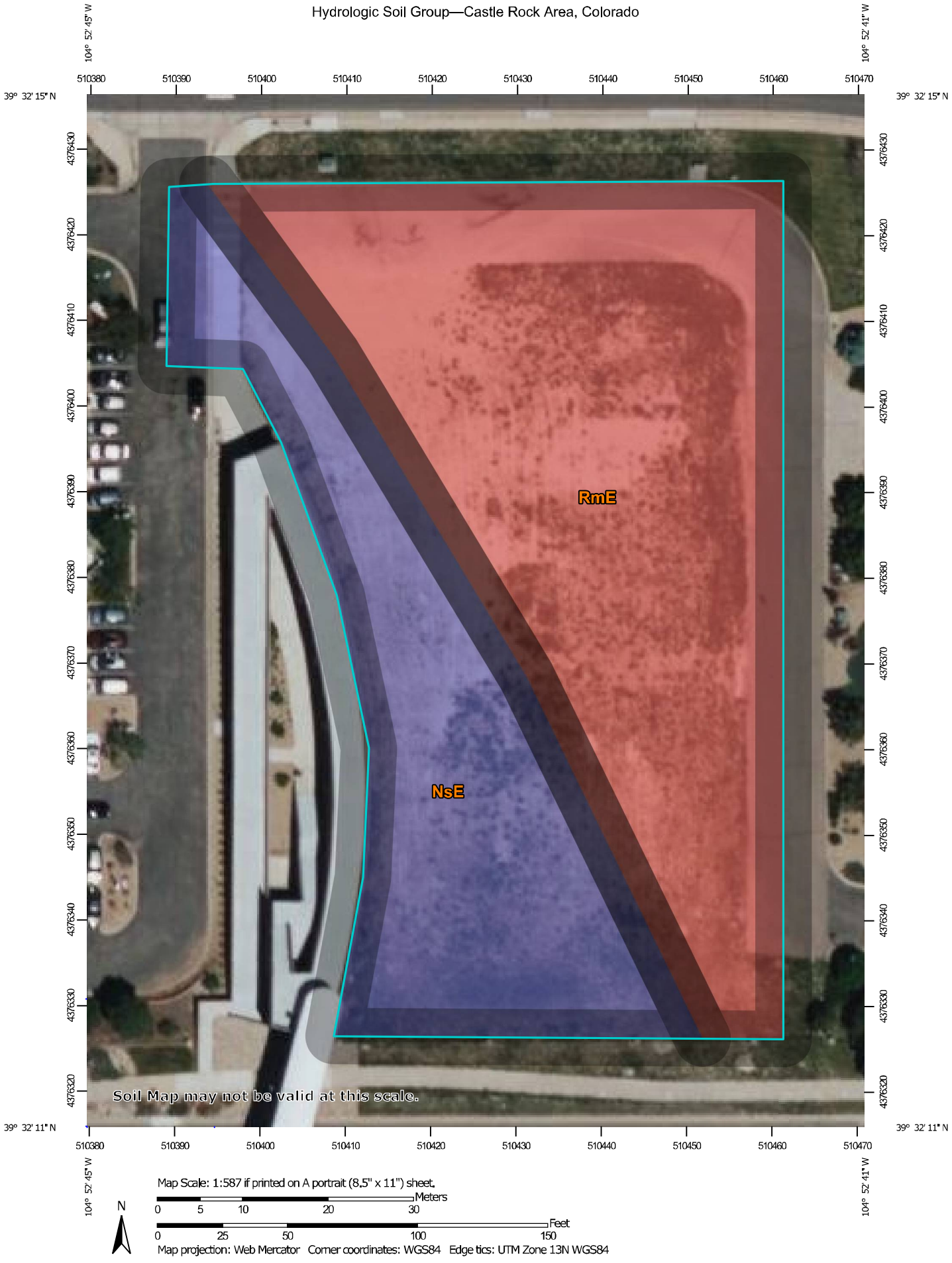
4. *Storm Drainage Design and Technical Criteria Manual,* Douglas County, current edition, https://www.douglas.co.us/public-works/stormwater/storm-drainage-design-and-technical-criteria-manual/.

5. *Urban Storm Drainage Criteria Manual – Volumes 1 through 3*, Mile High Flood District, current edition, https://mhfd.org/resources/criteria-manual.

6. *Phase III Drainage Report, Heritage Hills Filing No. 1-F*, JR Engineering, LTD., July 1999.

7. *Drainage Report and Erosion Control Plan For Commercial Federal Bank*, Huitt-Zollars, Inc., August 27, 2003.

VIII. APPENDICES



Map Scale: 1:587 if printed on A portrait (8.5" x 11") sheet.

N

Meters
0 5 10 20 30

Feet
0 25 50 100 150

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Castle Rock Area, Colorado
Survey Area Data: Version 16, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 9, 2021—Jun 12, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
NsE	Newlin-Satanta complex, 5 to 20 percent slopes	B	0.5	36.5%
RmE	Renohill-Buick complex, 5 to 25 percent slopes	D	0.9	63.5%
Totals for Area of Interest			**1.4**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

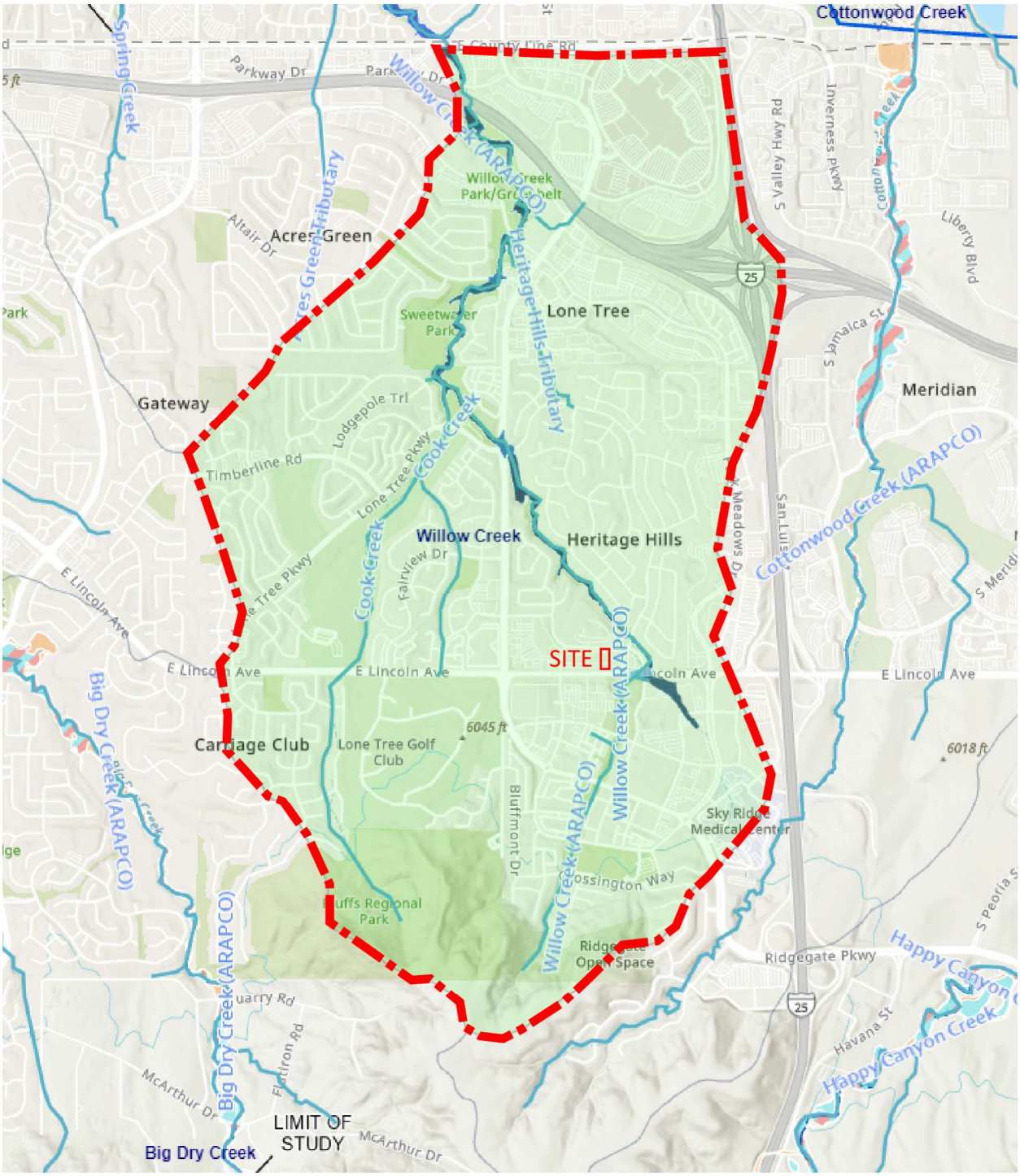
Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

MHFD General Data Viewer
MILE HIGH FLOOD DISTRICT



National Flood Hazard Layer FIRMette

FEMA

104°53'2"W 39°32'27"N

104°52'24"W 39°31'59"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance / Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

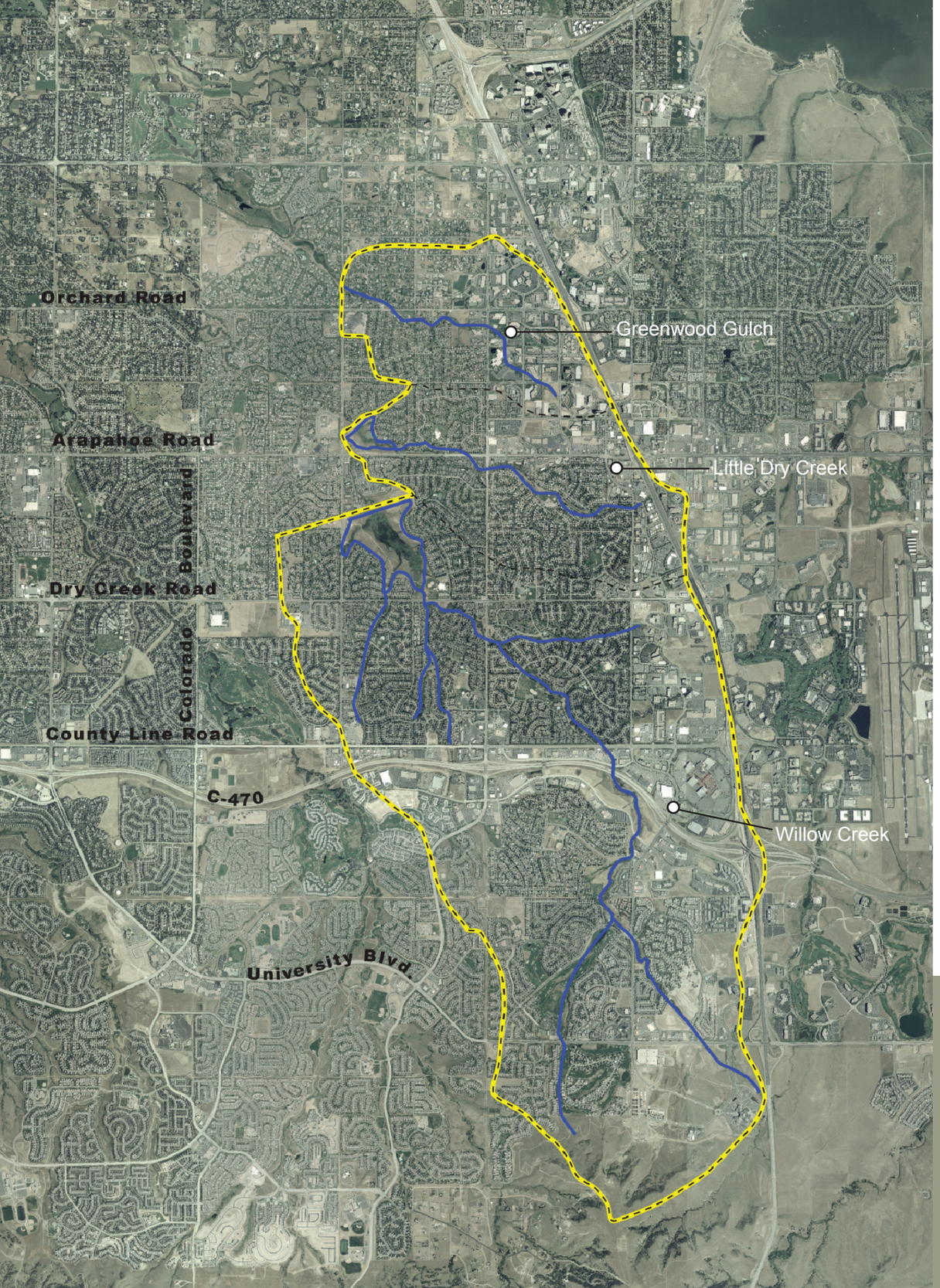
N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 11/14/2023 at 5:03 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.



Willow Creek, Little Dry Creek, and Greenwood Gulch Outfall Systems Planning Study

Planning Report

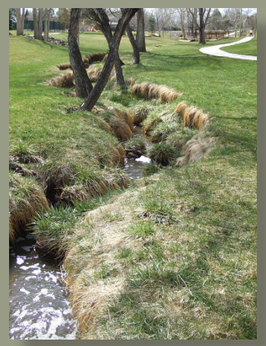
February 2010

Prepared for

Prepared by

CH2MHILL

9191 South Jamaica Street
Englewood, CO 80112-5946



Executive Summary

Purpose and Objective

The purpose of this report is to present the conceptual design of the Willow Creek, Little Dry Creek, and Greenwood Gulch Watersheds as shown in Figure ES-1, Study Area. This Outfall Systems Plan (OSP) is being developed for the Willow Creek, Little Dry Creek, and Greenwood Gulch Watersheds in Arapahoe and Douglas Counties. The purpose for preparing the OSP is to provide a comprehensive master drainage plan for the Study Area which establishes a framework for the development of drainage improvements within the Study Area. Specifically, the OSP discusses how urbanization has impacted the characteristics of the watersheds and the types of outfall drainageway systems required to mitigate the impacts to stormwater conveyance, flood management, stream stability, and stormwater quality.

The study is being done under contract to Urban Drainage and Flood Control District (UDFCD). UDFCD is joined by several other participating entities all of whom have jurisdiction over portions of the channels or the watersheds being studied. These entities include the City of Lone Tree (Lone Tree), the Southeast Metro Stormwater Authority (SEMSWA), City of Greenwood Village (Greenwood Village), Douglas County, and the South Suburban Parks and Recreation District (SSPRD), which in combination with UDFCD are collectively known as the Project Sponsors.

Planning Process

The purpose and scope for the project generally consists of hydraulic and hydrologic analysis, alternatives evaluation, selection of outfall systems and then conceptual design. The OSP is developed in two distinct phases, Alternatives Evaluation and Conceptual Design. The Alternatives Evaluation Phase included a determination of the hydrology associated with future development conditions for the Study Area. In addition to the hydrologic analysis, alternative outfall systems were identified and evaluated to help determine the most appropriate outfall systems. Section V of this report documents the development and evaluation of outfall systems associated with the Alternatives Evaluation phase.

The Project Sponsors reviewed the findings presented in the Recommended Plan and selected a preferred outfall system from the Alternatives Evaluation and authorized the development of a conceptual design of their preferred plan (Selected Plan) to be presented in the Conceptual Design Report. The conceptual design includes a more detailed look at actual conditions along the streams and provides a refined layout of facilities identified as part of the Selected Plan as well as an updated estimate of implementation costs.

The identification of the Selected Plan included consideration of the evaluations conducted during the Alternatives Evaluation Phase as well as input provided by stakeholders and the public during numerous progress meetings and during a public meeting. Progress meetings were held eight times during the course of the project to present work activities and to allow the study team to gather important information that might influence planning decisions. One public meeting, attended by over 50 residents and interested citizens, was held prior to the development of the alternative plans to gather input on flooding issues of concern and on preferred approaches to address these flooding concerns. A second public meeting, attended by 40 residents and interested citizens, provided feedback on the Selected Plan prior to finalizing this report.

Project Area Description

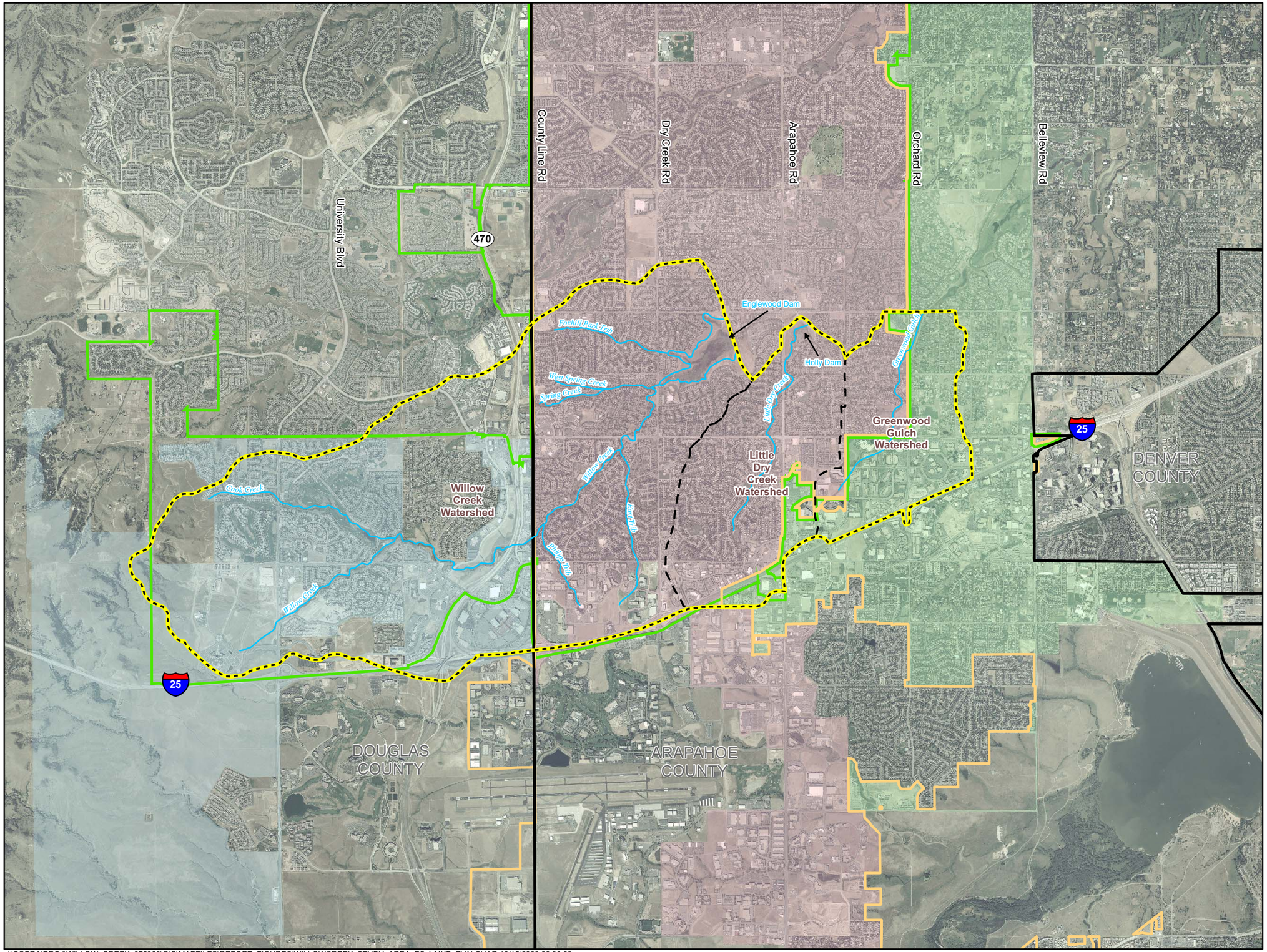
Willow Creek, Upper Little Dry Creek, and Greenwood Gulch are all tributary to Lower Little Dry Creek. Little Dry Creek flows from the southeast to the northwest and is a tributary to the South Platte River. The Study Area boundaries include Holly Street to the west and Interstate 25 (I-25) to the east. Major arterial roads through the Study Area include Colorado State Highway C-470, County Line Road, Dry Creek Road, Arapahoe Road, and Quebec Street. Several other collector and local roads are also within the Study Area.

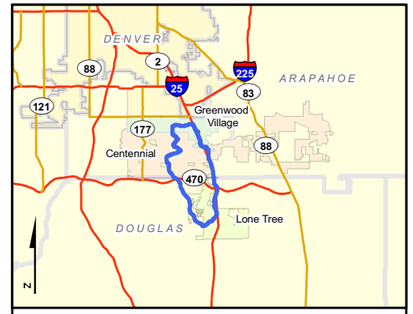
The thirteen (13) square mile Study Area is mostly composed of developed land, with a few scattered areas of open space consisting of a golf course and parks, and a portion of undeveloped land in the southernmost area of the Willow Creek Watershed. The existing residential subdivisions consist of medium to high density and low density developments. The medium density developments consist of approximately four homes per acre while the low density developments consist of approximately one home per several acres. The low density developments are located primarily in the Greenwood Gulch watershed. The drainages in the watersheds have been improved upon over many years and in general are in moderate to good condition.

A detailed hydrologic analysis was conducted as part of the study. Discharge estimates were determined for a variety of flooding events at several key locations within the three watersheds for both the developed and existing watershed conditions. Based on a review of the results by the Project Sponsors, it was concluded that the estimated flows between the two levels of development were sufficiently close that only the future conditions hydrology needed to be carried forward. As such, only future development conditions are being reported.

The hydrologic study incorporated two very important decisions made by the Project Sponsors. First, early in the hydrologic study it became evident that changes within CUHP had resulted in some fundamental differences in the representation of runoff from the watersheds. These programming changes created fairly significant differences in the runoff estimates, even when using the same input parameters. The sponsors asked that work on the hydrologic modeling be suspended until the programming anomalies could be reconciled. An updated version of CUHP was provided and the hydrologic evaluations were resumed. A calibrated model was developed from which existing and future condition runoff estimates were derived.

A second important decision was made that clarified how existing stormwater detention ponds would be represented in the model. The basins are filled with numerous stormwater detention ponds that were constructed in accordance with development regulations that prevailed at the time of construction. These provide valuable stormwater management controls and are generally well maintained by the special districts or homeowner's associations having jurisdiction. However, since most of these facilities are not actively under the control or being maintained by any of the Project Sponsors and their continued function as designed could not be assured, the decision was made to not include them in the representation of the existing basin conditions. Existing conditions hydrology includes only those stormwater detention facilities that are being maintained by one of the Project Sponsors. Future conditions hydrology also did not include these facilities nor did it include the benefits of any possible future detention ponds that might also be maintained by someone other than the Project Sponsors.





Watershed Location

Willow Creek, Little Dry Creek, and Greenwood Gulch Outfall Systems Planning Study

Legend

- Perennial Streams and Creeks
- Study Area
- Watershed Boundary
- SEMSWA Service Area
- SSPRD Boundary
- County Boundary

Municipalities

- Centennial
- Greenwood Village
- Lone Tree

Note: Urban Drainage and Flood Control District Service Area encompasses entire mapped area shown

N
W
E
S

0 2,000 4,000
Feet

WILLOW CREEK, LITTLE DRY CREEK, AND GREENWOOD GULCH STUDY AREA FIGURE ES-1

CH2MHILL

\\COBRA\PROJ\WILLOW_CREEK_372380\GIS\MAPFILES\REPORT_FIGURES\WILLOWCREEK_STUDY_AREA_ES-1.MXD ZVALCHAR 10/15/2009 08:30:09

The results of the hydrologic evaluations are summarized in Table ES-1.

TABLE ES-1
Summary of Baseline Hydrology Model Peak Flow Rates at Key Locations (future land use conditions and existing detention)

Location Description	SWMM Design Point	2-year (cfs)	5-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
Willow Creek							
Cook Creek at Lincoln	W7	34	115	154	303	371	471
Cook Creek	W16A	38	105	147	287	350	430
Willow Creek at Cook	W16B	266	421	512	882	1,015	1,145
Spring Creek at County Line	WP4	137	181	401	584	907	1,259
Spring Creek	W45	230	404	508	895	1,177	1,603
Willow at Yosemite	W23	675	1,073	1,254	1,813	2,092	2,519
Willow at Dry Creek Road	W52	1,633	2,737	3,318	5,475	6,666	8,564
Englewood Dam	P5	1,679	2,877	3,519	6,008	7,308	9,458
Little Dry Creek							
LDC at Arapahoe	L53	538	923	1,113	1,824	2,157	2,673
Holly Dam	P6	540	964	1,177	1,986	2,325	2,888
Greenwood Gulch							
Greenwood Gulch at Orchard	G72	610	1,017	1,206	1,845	2,075	2,490
Greenwood Gulch at Holly	O3	552	915	1,101	1,777	2,071	2,577

Alternative Analysis

A careful site assessment was conducted to identify problem areas within the three watersheds. This assessment found a number of problems. Table ES-2, Problem Area Description summarizes the identified problems within each of the drainageways.

TABLE ES-2
Problem Area Description

Watershed	Drainageway	Problem Description
Greenwood Gulch	Greenwood Gulch	Undersized crossings at major roadways, channel bank erosion and head cutting, exposed utility crossing, and flooding outside of channel banks and onto adjacent properties
Little Dry Creek	Little Dry Creek	Undersized crossings at major roadways, channel bank erosion, low flow channel degradation, head cutting, failing drop structures, high velocity flow, and detention pond overtopping
Willow Creek	Willow Creek	Undersized crossings at major roadways, channel bank erosion, low flow channel degradation, and failing drop structures
Willow Creek	Cook Creek	Localized channel bank erosion

Based on the identified problem areas and the flows for the future development conditions, four alternatives were developed. Alternate plans were formulated based on the requirements of the scope of services and are: 1) Repair Alternative; 2) Conveyance Alternative; 3) Detention Alternative; and, 4) Combination Alternative.

- Repair Alternative – The Repair Alternative constitutes addressing the existing problems that have been identified in the watersheds. This also includes improvements to increase the quality of storm water in the watershed. In general these include channel bank stabilization, construction of drop structures at head cuts, and repairing low flow channel erosion but not other efforts that improve infrastructure to meet current criteria. This alternative will not reduce flooding problems; however, it will reduce the degradation of the channel. This alternative creates the baseline condition that is included in all of the other alternatives.

- Conveyance Alternative – The full conveyance option includes improvements to assure that the 100-year peak flows can be conveyed through the drainage system while meeting the design criteria and overall project objectives. The improvements proposed are a combination of the improvements identified in the repair alternative and the inclusion of replacement of undersized culverts. There are a few reaches of channel that are experiencing high velocities or steep longitudinal slopes that also require additional improvements, such as channel armoring or drop structures.

- Detention Alternative – The detention option intends to address project objectives and violations of the stated criteria by reducing flow rates to levels that can be handled by the existing infrastructure. Conveyance capacity improvements are only included when detention alone is not able to address the problems. Recommendations to formalize a number of existing stormwater detention facilities that are privately owned and maintained are included as a part of this alternative and will require the local jurisdictions to obtain maintenance agreements and easements over the ponds to ensure that they continue to function.

- Combination Alternative – The team formulated an alternative that combines elements of the conveyance and detention alternatives into a comprehensive plan that may address problem areas in a more effective manner. This alternative attempts to utilize an effective combination of both conveyance and detention improvements to reduce costs and provide the greatest improvements to the watershed.

Within each of the identified alternatives, all proposed improvements comply with the prevailing local jurisdiction's criteria. For channels that are to be improved, geometry and depth will comply with jurisdictional requirements. Channels that are identified to be in a stable condition but do not meet current standards for geometry are not planned for improvement. Culverts were sized to prevent roadway or embankment overtopping and to have a headwater to depth ratio of less than 1.5. In all cases, the intent of the proposed improvements is to control the impacts of the 100-year flood on adjacent properties and public streets. For all road crossings the criteria is clear that no overtopping is allowed for any return period regardless of street classification. Proposed stormwater detention ponds can consist of new detention ponds that utilize UDFCD full-spectrum detention, formalizing existing detention ponds, and/or adding water quality outlets to existing structures. These improvements aim to more closely mimic natural stream flows in the watershed.

Improvements were identified for each alternative that met the stated objectives. A conceptual layout of the alternative improvements was developed and cost estimates prepared. These cost estimates were based on generalized unit costs and were intended to be used for comparative and decision making purposes

only. Included in these costs are estimates of construction costs, operation and maintenance costs, administrative and engineering, and land acquisition costs. An important decision was made regarding the representation of land acquisition costs. The Project Sponsors noted that, with only extraordinary exceptions, improvements would only be contemplated for construction if property owners were willing participants and were prepared to provide temporary or permanent easements to support the implementation. As such, the project team was directed to assume that land acquisition costs would generally be zero.

Recommended Alternative

Based on the evaluations, a recommendation was provided to the Project Sponsors. The Recommended Alternative varied by drainageway but generally contained the elements of the Combination Alternative with some minor enhancements. This alternative included making repairs to those areas where deteriorated channel conditions posed an imminent threat of damage and providing a combination of conveyance enlargements and additional detention to address capacity deficiencies and violations of stated criteria.

The Project Sponsors, after review of the recommendations, agreed that the Recommended Plan met the project objectives most effectively but proposed some minor enhancements to better leverage some of the existing infrastructure in the watershed. The Project Sponsors provided Notice to Proceed on July 27, 2009 authorizing the development of the Conceptual Design for the Selected Plan. The elements for the Selected Plan are described in general terms as follows:

Greenwood Gulch

The Selected Plan for Greenwood Gulch is the same as the Combination Alternative. This alternative includes all of the improvements recommended for the Repair Alternative and it formalizes existing detention storage infrastructure to reduce the level of improvements needed in the watershed. This also includes the improvements that are called out in the approved Verona Estates development plan. Because the existing detention in the watershed is primarily located in Greenwood Village; it is recommended that Greenwood Village obtain the necessary easements and maintenance agreements to formalize the detention. Both Greenwood Village and Centennial will experience benefits from this formalization, including lower infrastructure costs and reduced flooding.

Little Dry Creek

The Selected Plan for Little Dry Creek is very similar to the Combination Alternative with the addition of some localized recommended improvements. This alternative includes all of the improvements recommended for the Repair Alternative and it provides a reduction in stream flow and increased water quality by constructing detention in a drainageway that is devoid of stormwater flow controls. The new detention will be limited to property that is owned by SSPRD, such that property acquisition is not required. The detention will reduce the flow rates such that smaller infrastructure improvements are needed as compared to the conveyance alternative.

Willow Creek

The Selected Plan for Willow Creek is most similar to the Combination Alternative but includes some elements that leverage existing privately owned stormwater detention. There are localized repairs that will be made throughout the watershed to reduce the flood hazard. The construction of stormwater detention facilities throughout the watershed will increase the water quality as well as reduce the size of required infrastructure to pass the major storm event but the size of new stormwater detention facilities will be reduced from the Recommended Plan by upgrading some existing storage facilities to meet Project Sponsor specifications. The elements of the Selected Plan are shown on Figure ES-2, Selected Plan Elements.

Costs for the Selected Plan are shown in Table ES-3, Selected Plan Cost Summary.

Conceptual Design

Based on the elements of the Selected Plan described by the Project Sponsors, a Conceptual Design was developed. This design provides a higher level of resolution for each of the plan components and provides a basis for each of the Project Sponsors to develop more specific implementation strategies, prepare Capital Improvement Program budgets and initiate design and drainage easement acquisition efforts. Specific elements of the Conceptual Design are described for each reach in the following summary. Conceptual Design Drawings for the Selected Plan can be found in Appendix F, Plan and Profile Drawings.

Greenwood Gulch Watershed

Greenwood Gulch, through the study area, has seen significant improvements and in general does not require a large amount of repair. In the planned Verona Estates parcel the channel has incised and developed steep channel banks that require stabilization. A head cut has also migrated in this area to just downstream of the existing baffle chute drop that will be addressed with a grouted boulder drop structure.

The upper portion of the watershed has a significant number of stormwater detention ponds, however there are no defined water quality outlet structures included. Therefore, as a part of this alternative, water quality outlets are recommended.

The proposed formalization of detention ponds includes the 16 acre-feet upstream of Quebec Street and the 8.5 acre-feet of storage on the Orchard Draw tributary north of Greenwood Gulch. With the benefits of this detention accounted for in the watershed, flows are reduced and the existing Quebec Street crossing is adequately sized. The Monaco Way crossing still requires an additional 60" RCP to convey the 100-year event. The detention also reduces peak flow rates such that the channel along Orchard Drive has adequate capacity and does not need to be improved.

Little Dry Creek Watershed

Little Dry Creek at the downstream end of the study area flows through the Holly Dam open space. In this reach the channel has become deeply incised and has locations of vertical banks that are actively eroding. Channel repairs, as well as water quality improvements in the Holly Dam open space area are recommended to improve the drainageway. Upstream of Arapahoe Road the channel is experiencing low flow erosion that needs to be repaired to prevent erosion of the channel overbanks and side slopes. The remaining reaches in Little Dry Creek are experiencing localized erosion that needs to be repaired.

The Holly Dam was designed to provide a significant amount of stormwater detention to protect the area downstream from flooding. Upstream of this facility there is very little detention, and very little opportunity for detention. Because of the limited space available for detention many of the conveyance improvements are still required. However, with the detention that has been identified, smaller infrastructure upgrades are required.

The most significant detention pond proposed is upstream of the Spruce Street crossing. The proposed pond will fit entirely on SSPRD property and coordination with the School District is not required. This results in a 26 acre-foot pond. Utilizing this pond and formalizing the existing 6 acre-foot pond upstream of Yosemite Street, the required improvements to roadway crossings are reduced to the following:

- Krameria Way – Twin 8-foot by 7-foot CBC
- Quebec Street – New 48-inch RCP and Existing CBC's
- Spruce Street – New 72-inch RCP and Existing Twin 66-inch RCP
- Uinta Street – Twin 8-foot by 8-foot CBC
- Xanthia Street – Existing 60-inch RCP and New 18-inch RCP
- Yosemite Street – 60-inch RCP

The undersized collection system in the Walnut Hills Neighborhood can benefit from diverting the upper tributary basin comprised of office and commercial development. The diversion would occur by routing the collected flow from the existing storm water pond through a 48" RCP in Yosemite Street to the upper reach of Little Dry Creek. This will reduce the load on the existing Walnut Hills storm sewer system to reduce street and backyard flooding.

Willow Creek Watershed

The Willow Creek watershed has been significantly urbanized and as a result much of the watershed has been stabilized. Although these past improvements have benefited the watershed, there are multiple locations throughout the watershed that require bank stabilization, grade control, or low flow channel repair.

The Willow Creek watershed has a number of existing stormwater detention ponds that have easements that allow for future maintenance to occur and protect the ponds from ever being eliminated. These ponds were included in the Baseline Hydrology model and are assumed to remain in place as part of the Selected Plan. A number of other ponds were not included in the baseline hydrology because no formal easements exist. However, considerable benefit accrues from the flow reduction through these ponds. The Selected Plan calls for the formalization of a number of these ponds to reduce the flows in the drainageway such that the existing infrastructure does not need to be increased in size. Because the infrastructure in some locations is so severely undersized the amount of detention needed within the basin is larger than can be provided merely by formalizing existing detention. An additional nine (9) acre-foot pond is proposed on Willow Creek in Lone Tree, just south of C-470. Although no crossings are undersized in Lone Tree, this pond will provide benefit to the channel and infrastructure in the City of Centennial. Another large detention facility is located at Willow Creek Park upstream of Mineral Drive in Centennial. In order to eliminate overtopping of Quebec Street, a 39 acre-foot pond is required in addition to enlarging the crossing by adding twin 8-foot by 7-foot CBC's.

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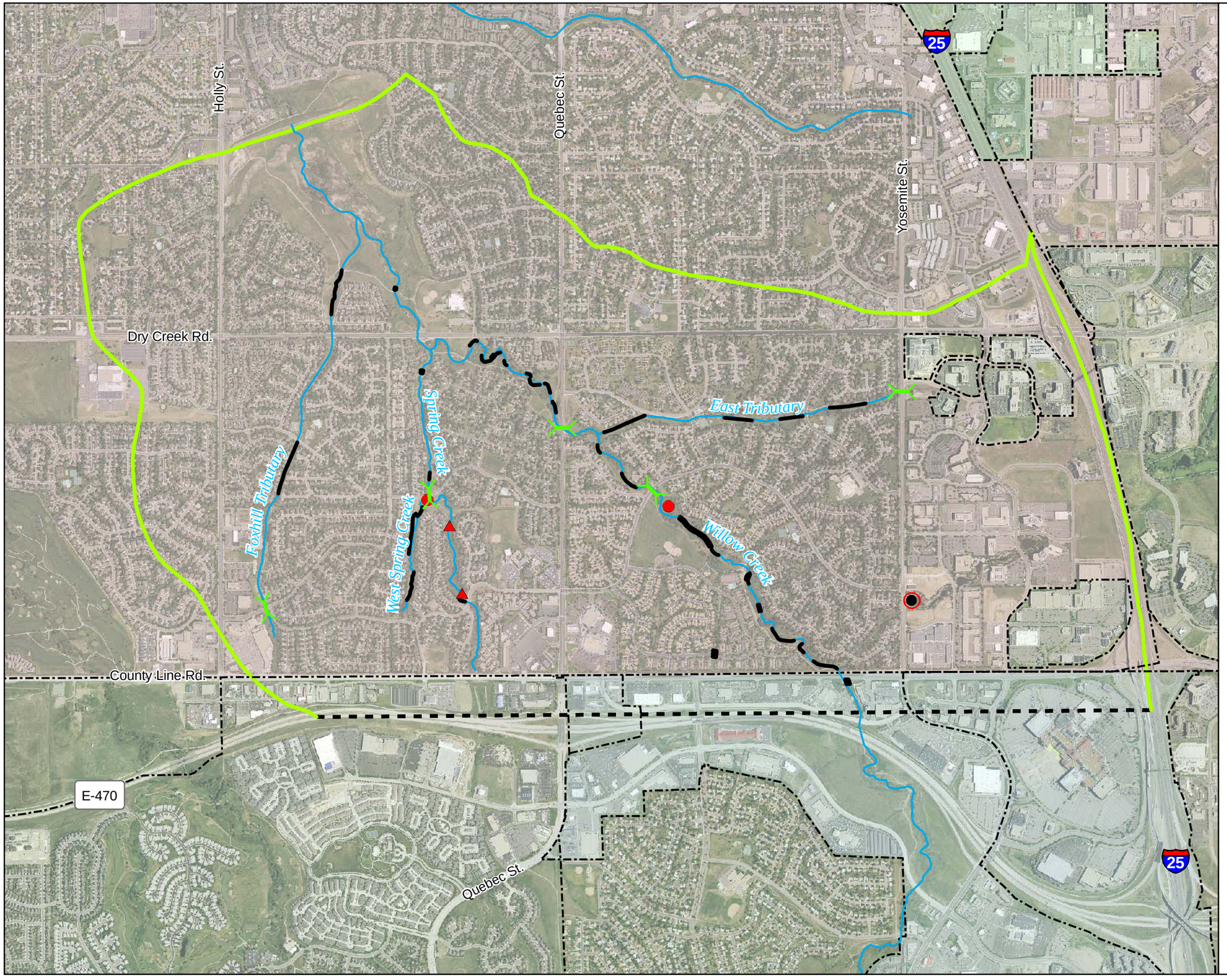

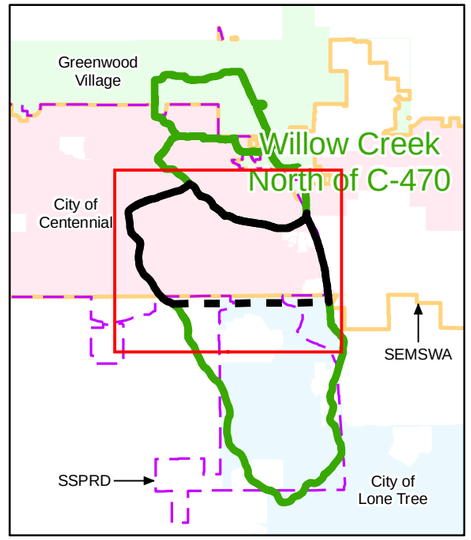

LEGEND

- New Drop Structure
- New Detention
- Formalize Detention
- Enlarge Culvert
- Bank Protection
- New Storm Sewer
- Low Flow and Bank Repairs
- Jurisdictions
- Drainage Basins

Municipalities

- Centennial
- Greenwood Village
- Lone Tree

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Selected Plan Elements
Willow Creek
Figure ES-2-WC(N)

CH2MHILL

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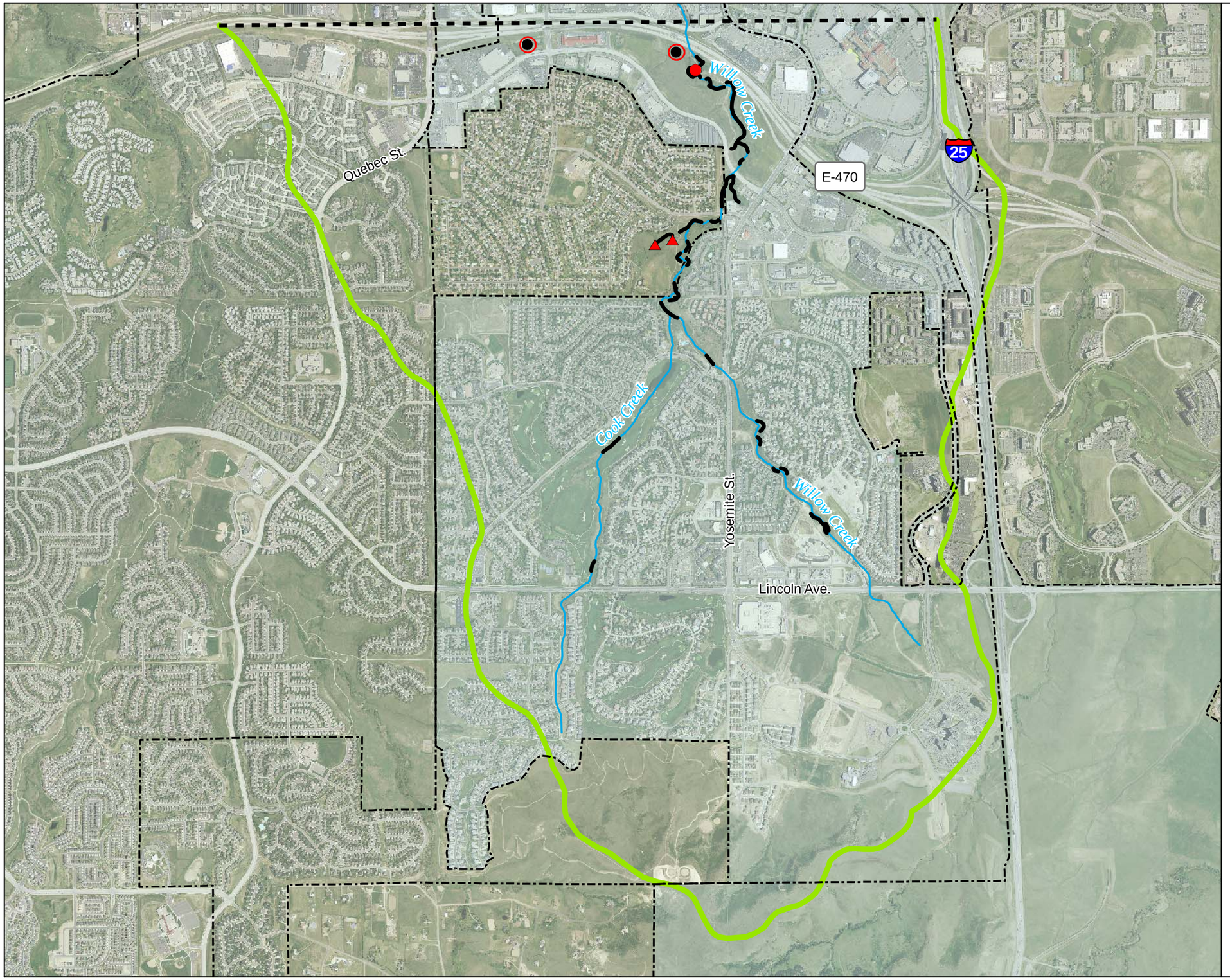

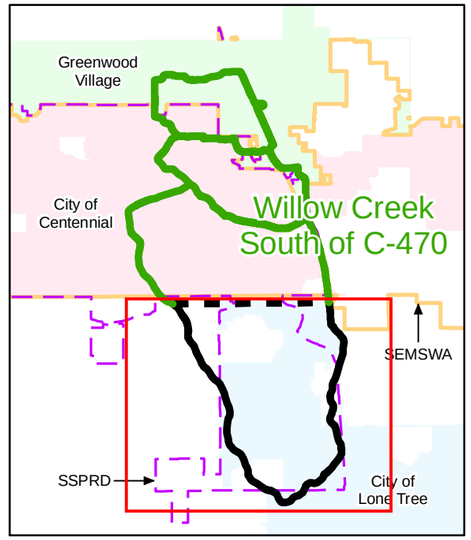

LEGEND

- New Drop Structure
- New Detention
- Formalize Detention
- Enlarge Culvert
- Bank Protection
- New Storm Sewer
- Low Flow and Bank Repairs
- Jurisdictions
- Drainage Basins

Municipalities

- Centennial
- Greenwood Village
- Lone Tree

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Selected Plan Elements
Willow Creek
Figure ES-2-WC(S)

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II. Study Area Description

Study Area

Willow Creek, Upper Little Dry Creek, and Greenwood Gulch are all tributary to Lower Little Dry Creek. Little Dry Creek flows from the southeast to the northwest and is a tributary to the South Platte River. The Study Area boundaries include Holly Street to the west and I-25 to the east. Major arterial roads through the Study Area include Colorado State Highway C-470, Arapahoe Road, Quebec Street, Dry Creek Road, County Line Road, Park Meadows Drive, and Lincoln Avenue. Several other collector and local roads are also within the Study Area. Figure B-1, Study Area, Appendix B shows the location of the Study Area.

The thirteen (13) square mile Study Area is mostly composed of developed land, with a few scattered areas of open space consisting of a golf course and parks, and a portion of undeveloped land in the southernmost area of the Willow Creek Watershed. The existing residential subdivisions consist of medium to high density and low density developments. The medium density developments consist of approximately four homes per acre while the low density developments consist of approximately one home per several acres. The low density developments are located primarily in the Greenwood Gulch watershed.

Land Use

The Study Area is almost fully developed with about 50 percent residential areas, 40 percent commercial areas clustered along the highways, and the remaining areas are highways and open space.

The land use incorporated into the baseline hydrology model reflects future land use conditions. The future land use is expected to be very similar to existing conditions with only a few additional developed areas. The purpose of this baseline model is to reflect basin development conditions at future percent imperviousness and estimate the amount of stormwater runoff from the Study Area for planning purposes.

Land use information was provided by Lone Tree, Greenwood Village, SEMSWA, and Douglas County in GIS format or in PDF files that were digitized and imported into a GIS map. Percent Impervious Values per basin were calculated using GIS. The area of land use coverage within a subcatchment was determined then weighted to the total area of the subcatchment and the weighted averages summed to create a composite for each subcatchment's percent impervious value. The selection of percent impervious values for land use types was from the *USDCM,* Volume 1, Tables RO-3 and RO-5. One exception is the "future commercial" land use type which reflects the currently undeveloped areas in the watershed which are zoned for commercial development. Based on new planning criteria for Lone Tree in Douglas County and Arapahoe County, new commercial developments must leave a minimum of 20 percent to 25 percent open space on the lot (reference: Arapahoe County Land Development Code, Current Zone District B-1, Administrative and Professional Offices and Lone Tree Zoning Code, Article XII C – Commercial District). Therefore on new commercial developments, 75 percent imperviousness was used.

Table 2-1, Land Use and Impervious Values, shows the percent impervious selected values for the land use descriptions provided by the Sponsors of the project.

TABLE 2-1
Land Use and Percent Impervious Values

Land Use Description	Percent Impervious Value
Commercial	95%
Future Commercial	75%
Industrial	85%
Single Family (4 units per acre, 3,000 SF)	48%
Multi-Family	75%
Open Space	5%
Large Lot (1 Unit Per 2 to 2.5 Acres, 5,000 SF)	28%
Highways	98%

The percent of imperviousness used in the hydrologic model are shown in Table B-1, while future land use categories are displayed on Figure B-2, both of which are found within Appendix B attached to this report.

Soil Characteristics

Hydrologic soil classifications within the Willow Creek, Little Dry Creek and Greenwood Gulch watersheds are summarized on Figure B-3, Soil Classification, Appendix B. Soils data were obtained from the Soil Survey Geographic (SSURGO) Database, provided by the Natural Resources Conservation Service (NRCS).

The Study Area is predominately composed of Type C (moderately low infiltration and moderately high runoff potential) soils with clusters of Type D soils (low infiltration and high runoff potential) around the Englewood Dam and Holly Dam, the Willow Creek channel, and the undeveloped southern portion of the Willow Creek watershed. Type B soils (moderately high infiltration and moderately low runoff potential) are found south of C-470 along Willow Creek, and a few clusters of Type A soils (high infiltration and low runoff potential) are located in the eastern portion of Willow Creek watershed.

Previous Studies

In the past, two UDFCD Major Drainageway Planning (MDP) Studies that include portions of the Study Area were submitted in 1974 and in 1986. The *Major Drainageway Planning - Little Dry Creek (1974)* MDP made recommendations for six regional flood control dams along Willow Creek, Little Dry Creek and Greenwood Gulch and their respective tributaries. The *Hydrologic Analysis, Little Dry Creek and Tributaries (1986 Study)* updated the hydrology for Little Dry Creek downstream of Holly Dam and Englewood Dam.

For the Willow Creek watershed, no previous hydrologic study has been found that is comparable in size and scope with the hydrology developed in during this study. Most studies have been performed for the

entire Little Dry Creek Watershed, which includes Willow Creek as a tributary. However, no detailed analysis of the Willow Creek watershed has been published to date.

The 1974 report includes the entire Little Dry Creek watershed, including Greenwood Gulch and Willow Creek. Hydrology presented in this OSP study contains a higher percent impervious for the future conditions than the 1974 report. Within this OSP, an average of 60 percent imperviousness is presented opposed to the 32 percent imperviousness used in the 1974 report. The 100 year storm duration in the 1974 report is 3 hours long compared to a 2 hour storm duration used within this OSP. Also, a more refined delineation of the watershed is presented in this OSP study compared to the 1974 report.

The 1986 study was conducted in order to update the 1974 hydrology for the Little Dry Creek Watershed downstream of Holly Dam and Englewood Dam. For the hydrologic analysis, the upstream portion of the watershed was included to accurately represent the flows into the downstream portion. However, the Upper Little Dry Creek and Willow Creek basins were not delineated into sub basins, resulting in very coarse hydrologic evaluation. Also, the hydrology was based on 3-hour rainfall duration with a total depth of 2.97 inches. No results were given for the Upper Little Dry Creek and Willow Creek basins.

Flow rates reported in the 1974 and the 1986 studies are presented in Table 2-2, Flow Rates Reported in Previous Studies for select design points.

TABLE 2-2
Flow Rates Reported in Previous Studies

	1974 Master Plan			1986 Report	
		Peak Flow (cfs)		Peak Flow (cfs)	
LOCATION DESCRIPTION	Design Point	10-year	100-year	10-year	100-year
Little Dry Creek at Quebec Street	L04	1,000	1,400	NA	NA
Willow Creek at County Line Road	W02	2,700	4,100	NA	NA
Little Dry Creek at Arapahoe Road	L53	1,300	1,800	NA	NA
Greenwood Gulch at Holly Street	O3	1,400	2,100	1,482	2,284
Greenwood Gulch at Orchard Road	G72	1,100	1,600	1,482	2,284
Confluence of Spring Creek and Willow Creek	W45	1,000	1,500	NA	NA
Spring Creek at County Line Road	WP4	770	1,150	NA	NA

Outfall Description

The study area has been influenced greatly by urbanization, primarily residential and commercial. Because of urbanization there are multiple roadway crossings at the drainagway locations. Table 2-3, Roadway Crossing Summary, summarizes the roadway crossings in the watershed and includes the roadway classification, crossing material, and crossing size.

TABLE 2-3
Roadway Crossing Summary

Drainage	Jurisdiction	Road Crossing	Roadway Type	Crossing Type	Size
Greenwood	Greenwood Village	Holly Street	A (local collector)	Bridge	9' opening, 52.5' wide
Greenwood	Greenwood Village	Orchard Road	B (Major collector)	Bridge	12.6' opening, 46' wide
Greenwood	Centennial	Monaco Way	A (local collector)	Twin CBC	8' x 6'
Greenwood	Greenwood Village	Quebec Street	C (Arterial)	Triple CMP	2 - 54", 1 - 72"
Little Dry Creek	Centennial	Krameria Way	A (local collector)	Twin RCP	102" & 84"
Little Dry Creek	Centennial	Arapahoe Road (2008 Design)	C (Arterial)	Twin CBC	12'x10' & 12'x8'
Little Dry Creek	Centennial	Quebec Street	C (Arterial)	Single CBC	10'x7'
Little Dry Creek	Centennial	Spruce Street	A (local collector)	Twin RCP & single RCP	2 - 66" & 1 - 60"
Little Dry Creek	Centennial	Uinta Street	A (local collector)	Twin RCP	66"
Little Dry Creek	Centennial	Xanthia Street	A (local collector)	Single RCP	60"
Little Dry Creek	Centennial	Yosemite Street	B (Major collector)	Single RCP	36"
Willow – Foxhill Park Trib	Centennial	Hinsdale Avenue/Dry Creek Road	C (Arterial)	Single CBC	8'x6'
Willow	Centennial	Dry Creek Road	C (Arterial)	Bridge	10' opening, 48' wide
Willow	Centennial	Quebec Street	C (Arterial)	Twin CBC	14'x10'
Willow – East Trib	Centennial	Rosemary Way	A (local collector)	Twin CMP	72" & 96"
Willow – East Trib	Centennial	Willow Way	A (local collector)	Single CMP	84"
Willow – East Trib	Centennial	Yosemite Street	B (Major collector)	Single RCP	60"
Willow	Centennial	Mineral Drive	A (local collector)	Twin Arch	about 10'x20'
Willow	Centennial /Lone Tree	County Line	C (Arterial)	Triple CBC	12'x10'
Willow	Lone Tree	C470/Parkway Drive	C (Arterial)	Triple CBC	12'x12'
Willow	Lone Tree	Park Meadows Drive	C (Arterial)	Quadruple CMP	3x96" & 1x144"
Willow	Douglas County	Maximus Drive	B (Major collector)	Twin CMP	120"
Willow*	Lone Tree	Heritage Hills Parkway/ Yosemite Street	B (Major collector)	Twin CSP	96”
Cook Creek*	Lone Tree	Lone Tree Pkwy	B (Major collector)	Single RCB	3’ x 13’
Willow*	Lone Tree	Lincoln Avenue	C (Arterial)	Twin CMP	66”
Willow	Lone Tree	Heritage Hills Pkwy	B (Major Collector)	Twin CBC	11’ x 4’

TABLE 2-3
Roadway Crossing Summary

Drainage	Jurisdiction	Road Crossing	Roadway Type	Crossing Type	Size
Cook Creek*	Lone Tree	Lincoln Avenue	C (Arterial)	Single CMP	84”
Willow – Spring Creek	Centennial	Mineral Avenue	B (Major collector)	Single CBC	9'x9'
Willow – Spring Creek	Centennial	Otero Avenue	A (Local collector)	Single CBC	10'x8'
Willow – Foxhill Park Trib	Centennial	Kettle Avenue	A (local collector)	Double CMP	36"
Willow – Foxhill Park Trib	Centennial	Otero Avenue	A (local collector)	Two RCP	24” and 36”

Note: * Culvert crossings at pond outlets were included in the pond analysis.

Greenwood Gulch Outfall Description

Greenwood Gulch, UDFCD Drainageway ID 5401, is characterized by an urbanized watershed with an improved channel section for most of the study area. Greenwood Gulch generally flows from the east to the west and has approximately 2.7 miles of stream length including tributaries. The drainageway begins in the Denver Technological Center where it is primarily piped to multiple on-site stormwater detention ponds. From this commercial area, the channel passes under Quebec Street and flows toward the west through the City of Centennial. The portion of Greenwood Gulch located in Centennial begins as a turf grass lined channel through a commercial development and leaves through a large concrete baffle chute drop structure. From this location, just west of Quebec Street, Greenwood Gulch travels through an undeveloped parcel which is planned to be developed as Verona Estates. Here the channel is actively eroding and deeply incised. The channel leaves this undeveloped parcel and continues west behind residential single family homes. The reach of Greenwood Gulch upstream of Monaco Way was improved in 2007 by SEMSWA and UDFCD. The improvements included channel grading, bank armoring, grouted boulder drop structures, and channel revegetation. A new box culvert crossing at Monaco was installed in 2001. Downstream of the Monaco crossing the channel continues behind single family residences in a turf grass lined channel that is maintained by the South Suburban Parks and Recreation District. This reach has a series of grouted boulder drop structures and is well cared for.

Greenwood Gulch continues to the west and re-enters Greenwood Village through a privately owned open area which includes a trail system. The channel through this area is in a more natural condition with native grasses and willows lining the channel bank. The channel is experiencing erosion in this area and has locations of very steep channel banks. The channel then passes under the Orchard Road Bridge and parallels Orchard Drive. The channel in this reach is narrow and only three to five feet deep. The channel is bounded by Orchard Drive to the north and homes to the south. The channel has been improved through this reach and is characterized by grass lined banks, boulder edging in spots, and grouted boulder drop structures. Greenwood Gulch continues to the west under the Holly Street Bridge and exits the Study Area.

Little Dry Creek Outfall Description

Little Dry Creek, UDFCD Drainageway ID 5400, is the major drainageway to which both Greenwood Gulch and Willow Creek outfall. The portion of Little Dry Creek studied in this project is the upper most reach of the channel from I-25 to the Holly Dam. Little Dry Creek generally flows from east to west and has approximately 3.3 miles of stream length including tributaries. Little Dry Creek in the project area generally flows through residential areas and crosses major roadways including Yosemite Street, Quebec Street, and Arapahoe Road. At the upstream limits of the watershed, runoff from I-25 is collected and discharged to a water quality pond adjacent to the highway. Runoff is also collected from the commercial area east of Yosemite in a stormwater detention pond and is piped under Yosemite to the west. The creek flows through a residential single family home development toward Quebec Street. This reach is characterized by a grass-lined channel with boulder low flow edging through portions of the reach and willows along much of the channel. The channel has mature trees along the channel banks and has a number of grouted boulder drop structures along the reach. Within neighborhoods there are a few roadway crossings of Little Dry Creek. As the creek flows to the west it crosses under Quebec Street and passes between a series of town homes. This reach has a well defined grass lined channel with a riprap lined low flow channel. A series of grouted riprap drop structures in the reach prevents channel degradation. The channel then flows to the north to Arapahoe Road. This crossing has been designed for improvements to include a pedestrian underpass and is planned for construction in 2009. The channel then flows to the west paralleling Arapahoe Road on the north. This channel is characterized by vertical concrete check structures that provide stabilization under large events. The channel then crosses under Krameria Street and flows into the Holly Dam open space. The channel in upper portions of the open space is deeply incised and has vertical banks in many locations. The channel is not threatening existing facilities or infrastructure in the open space area.

Willow Creek Outfall Description

Willow Creek, UDFCD Drainageway ID 5402, has the largest contributing area to the downstream project limit of Holly Street. In general, flow in the Willow Creek watershed is from the south to the north and has approximately 15.4 miles of stream length including tributaries. The Willow Creek drainageway includes a series of tributary streams that make up the stream network for the watershed. Each of the reaches is discussed separately below.

Willow Creek Mainstem

The mainstem of Willow Creek begins near the southern project limits upstream of Lincoln Avenue. This area is adjacent to the Sky Ridge Hospital. There is not a well defined channel in this reach; however, the new development constructed a trapezoidal channel with drop structures on a minor tributary to the west of the mainstem. An existing stock pond collects flows from Willow Creek, just south of Lincoln Avenue and pipes the flow under the road to the north. The small un-named tributary to the west of the Lincoln crossing discharges to a stormwater detention pond that also discharges to the mainstem of Willow Creek north of Lincoln. The reach located between Lincoln Avenue and Heritage Hills Parkway has been improved and is characterized by a riprap lined low flow channel and grass lined channel banks. Downstream of the Heritage Hills Parkway crossing the channel has been encroached upon by residential development as well as an elementary school. The channel is lined with mature vegetation but there are multiple locations where bank erosion, most frequently at the outside bends, occurs. There is a single, large grouted riprap drop structure in the middle of this reach to provide grade control. The channel discharges to a regional stormwater detention pond that is adjacent to Yosemite Street.

Willow Creek exits the regional pond under the intersection of Heritage Hills Parkway and Yosemite Street and passes behind the Lone Tree Library into open space. It is in this reach that Cook Creek joins with the Willow Creek mainstem. The Willow Creek bike trail parallels the channel from this reach to the downstream limits of the study at Englewood Dam. The channel through this reach is deep and narrow

with locations of low flow channel degradation and bank erosion. Vegetation in this reach is mature with various tree species, willows, and native grasses. The channel continues to the north and crosses both Maximus Drive and Park Meadows Drive. As the channel leaves the open space and enters a more urbanized setting the vegetation along the channel is characterized by more grasses and fewer willows and trees. The channel here is unimproved and is experiencing active low flow channel erosion. Downstream of the Park Meadows Drive crossing the channel enters a large open space that is adjacent to Colorado Highway C-470. The channel in this reach is deeply incised and meanders significantly. The channel banks are actively eroding and are, in many locations, vertical with no vegetative cover in this area. Willow Creek flows to the north through culverts under C-470 and Parkway Drive. The channel then flows between commercial developments in an improved channel with grouted boulder drop structures. Willow Creek then exits Lone Tree and Douglas County through box culverts under County Line Road.

The reach of Willow Creek downstream of the County Line Road crossing is bounded on both sides by residential development. The channel flows in a northerly direction and is lined by mature cottonwood trees and willows at the channel's edge. This reach of channel has been improved and has multiple grouted boulder drop structures and locations of riprap bank protection or boulder lining. The channel continues toward the northwest and parallels the north side of the Willow Creek Park. The channel through this reach is similar to the channel immediately upstream with large trees and mature vegetation. Willow Creek crosses Mineral Drive and flows toward the Quebec Street crossing and the confluence with the East Tributary. The reach between Mineral Drive and Quebec Street also has very mature vegetation and large trees. There are locations of bank erosion mostly located at the outside of channel bends. The channel grade has been stabilized by a large concrete baffle chute drop structure located downstream of the confluence with the East Tributary.

Downstream of the Quebec Street crossing, Willow Creek curves in large meanders and crosses the Willow Creek trail in multiple locations. The channel in this reach is more incised than reaches upstream. Bank erosion is more severe in this reach and is again focused on the outside of channel bends. Vegetation in this reach is mature; however there are fewer willows at the channel bottom and more upland plants than in other reaches. This reach of Willow Creek generally flows to the west and confluences with Spring Creek prior to crossing Dry Creek Road. The channel flows through a sedimentation facility upstream of the bridge crossing to remove sediment prior to the channel reaching Englewood Dam.

Willow Creek flows to the north through the Dry Creek Road Bridge and enters the Englewood Dam open space. Here the channel has wide overbanks and a low flow channel that loses definition. The channel spreads out into a large wetland area.

Cook Creek

Cook Creek is an approximately 1.6-mile long tributary to Willow Creek located entirely in Lone Tree. The upper reaches of Cook Creek are bordered by single family residential development. The channel has been improved with grouted boulder drop structures and has turf grass overbanks. The channel discharges into a stormwater detention pond just upstream of Lincoln Avenue. The pond outfalls to Cook Creek on the Lone Tree Golf Course. The channel on the golf course is characterized by dense willows along the water edge and a series of drop structures to control the grade. Beyond the willows, the overbanks are characterized by golf course maintained grasses. The channel flows into a large stormwater detention pond that has a large permanent pool and is a feature on the golf course. The outfall of the pond passes under Lone Tree Parkway and discharges adjacent to the Lone Tree Civic Center. Cook Creek continues to the north through an open space area and confluences with the mainstem of Willow Creek. The open space channel is characterized by a wide channel bottom with dense wetland vegetation. In this reach there are two drop structures that provide grade control for Cook Creek downstream of Lone Tree Parkway.

Spring Creek/West Spring Creek

The Spring Creek tributary to Willow Creek flows from south to north and originates in Douglas County. The channel upstream of County Line Road is well defined and densely vegetated. The channel flows through a box culvert under Colorado Highway C-470 and outfalls into a large regional stormwater detention pond located between C-470 and County Line Road. The pond outfalls into a Bureau of Reclamation Type 6 energy dissipation structure on the north side of County Line Road. From the Type 6 structure Spring Creek flows behind a townhome complex that has constructed gabion retaining walls on the east side of the channel. This reach has a series of drop structures that provide grade control prior to crossing Otero Avenue through a box culvert. The outlet of the box culvert is directed toward the back yard of a single family residence where the channel has eroded vertically on the west bank. The reach downstream of Otero Avenue is heavily vegetated and access is extremely difficult. The channel is very deep with homes located thirty to forty feet above the channel invert. The invert of the channel is experiencing active head cutting and is migrating toward the Otero Avenue crossing. Spring Creek confluences with West Spring Creek just upstream of the Mineral Avenue crossing and continues to flow to the north. The channel downstream of Mineral Avenue is less densely vegetated and not as deep as the upstream reach. Spring Creek, from this reach to the confluence with Willow Creek, has a rock lined low flow channel with grouted boulder drop structures that have stabilized the channel. The overbanks in this reach are maintained turf grass. A trail parallels the channel in this location and there are mature trees along the trail, giving this reach a parkway feel.

East Tributary

The East Tributary to Willow Creek flows from east to west and originates in the Panorama Park office park. The runoff from the commercial area is collected in the Panorama Park stormwater detention pond just east of Yosemite Street. The pond discharges to the East Tributary into a linear park that is bordered by single family homes. For much of the channel between Yosemite and Rosemary Way, the low flow channel is boulder lined, and the overbanks are maintained turf grass. Through this reach there are multiple pedestrian crossings of the channel as well as grouted boulder drop structures.

Downstream of the Rosemary Way crossing the channel parallels Jamison Drive and is no longer in a linear park. The channel between the confluence with the mainstem of Willow Creek and Rosemary Way is trapezoidal in shape with an approximately 8' wide bottom and native grass lined channel banks. There are a few drop structures that are providing channel grade control through this reach.

Foxhill Park Tributary

The Foxhill Park Tributary flows from south to north and is located to the west of Spring Creek. The channel originates north of County Line Road in a stormwater detention pond south of Otero Avenue. The pond is heavily vegetated and it does not appear that it is actively maintained. The pond outfalls to the channel north of Otero Avenue where a series of nine grouted boulder drop structures provide grade control for the channel. The channel is adjacent to a local park and the overbanks are maintained turf grass. Downstream of the park the channel is trapezoidal in shape and bounded by single family residences on either side. The channel continues to the north and crosses Kettle Avenue and enters a reach that is well maintained and paralleled by a trail. The reach downstream of Kettle Avenue is stabilized by two large grouted boulder drop structures. The Foxhill Park Tributary crosses Dry Creek Road and enters the

Englewood Dam open space. This reach of the channel is experiencing active bank erosion and head cutting.

Wetland and Riparian Zones

Greenwood Gulch

Greenwood Gulch is an approximately 1.75-mile-long perennial stream that is tributary to Little Dry Creek. The headwater area of Greenwood Gulch is dominated by high density commercial (i.e., office park developments), with the lower reaches surrounded by residential development. In addition, the channel flows through the William McKinley Carson Park. The Palos Verdes Park and the Castlewood Park (two regional parks) also are located in proximity to the floodplain of the Gulch.

A majority of the drainage, along with the adjacent floodplain and associated wetlands, have been significantly altered through commercial and residential development. The headwaters of Greenwood Gulch occur within a large commercial development, and the primary drainage channel has been significantly altered in this area. Large open water ponds and drainage channels are characteristic of the headwaters area. The stretch of the gulch occurring west of Quebec Street remains in a semi-natural state. However, high rates of runoff in the upper headwater reach have severely degraded the overall condition of the channel and associated emergent wetlands. Further downstream, a significant restoration effort has been undertaken to control erosion, enhance wetlands, and improve the natural habitat for a large stretch of the drainage.

Due to the amount of disturbance, most biological communities adjacent to the primary drainage channel and adjacent floodplain have been significantly altered. Inclusions of small pockets and bands of riparian scrub/shrub occur in favorable oxbows and some remaining natural drainage areas. While the adjacent vegetation communities have been altered, the riparian scrub/shrub and non-native grasslands do support a variety of plant and animal species. These species rely on these habitats for optimal growth and success.

Two primary types of wetlands occur in the drainage: palustrine emergent and palustrine scrub/shrub. Palustrine emergent wetlands are characteristic of areas that are hydrologically associated with shallow depressions and pockets that do not receive high runoff. Wetland vegetation is generally herbaceous and includes species such as sedges, bulrushes, cattails, reed canarygrass, and panicled aster. Some shrubby species such as sandbar willow were present.

Palustrine scrub/shrub wetlands are hydrologically associated with the drainage floodplain and occur in proximity to the primary drainage channel. These areas are dominated by woody vegetation less than 20 feet tall. Plants include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. Vegetation is dominated by shrubby species such as sandbar willow but may also contain herbaceous species such as sedges, bulrushes, cattails, reed canarygrass, and panicled aster. An illustration of wetland and habitat inventory in Greenwood Gulch is given on Figure E1 in Appendix E.

Little Dry Creek

Little Dry Creek is an approximate 2-mile-long perennial stream (within the Study area) that is tributary to South Platte River. In the 1970s, a master drainage plan was completed for the Little Dry Creek basin. The plan recommended the construction of six regional flood control dams along Willow Creek, Little Dry Creek and Greenwood Gulch and their respective tributaries.

Portions of the drainage were improved by the 1980s flood control construction projects and additional channelization occurred by adjacent commercial and residential development. The existing Holly Reservoir contains an extensive emergent cattail wetland. The drainage channel leading to the reservoir primarily west from Krameria Way, remains in a semi-natural state and is surrounded by a riparian scrub/shrub and forest. Primary trees species on the higher margins of the channel and floodplain include cottonwood and Russian olive interspersed with willow species in the lower elevations. Russian olives are noxious weeds that should be removed by the local jurisdictions.

The channel has been significantly altered from the intersection of Krameria Way, parallel to Arapahoe Road, and through the residential development until the intersection of Quebec Street. The majority of this drainage lacks riparian areas or emergent wetlands, since the adjacent vegetation is actively managed.

At the intersection of Quebec Street bearing east to Spruce Street, the channel returns to a semi-natural state and the adjacent floodplain contains inclusions of riparian areas along with interspersed emergent wetlands. From Spruce Street to the terminus of the study area, the channel along with the adjacent floodplain and associated wetlands has been significantly altered by the adjacent commercial and residential development.

The higher elevation stream banks within the study area are lined with landscaped areas and upland grasslands dominated by introduced species such as Kentucky bluegrass, smooth brome, and the noxious weed Canada thistle. Small to large trees such as the native peachleaf willow and introduced Siberian elm are scattered along the banks of the creek and surrounding uplands. Because most of the stream banks and stream bottom have been eroded, only small pockets of palustrine emergent wetlands are present. Most of the wetland patches along Little Dry Creek are dominated by herbaceous wetland species such as Emory's sedge, prairie cordgrass, and meadow fescue. An illustration of wetland and habitat inventory in Little Dry Creek is given on Figure E2 in Appendix E.

Willow Creek

Willow Creek is an approximate 5-mile-long perennial stream (within the Study area) that is tributary to Little Dry Creek. The headwater area of Willow Creek is in a transitional urban area that is being rapidly developed. The watershed is located within portions of undeveloped foothill areas and high density commercial and residential development.

The amount of adjacent floodplain disturbance is highly varied over the course of the watershed. An existing riparian community dominates the floodplain, and is evident along a majority of the mainstream channel. Exceedingly dense groves and pockets of healthy riparian communities were identified at numerous locations. In general, the natural riparian vegetation is confined to areas that have residential and commercial development setback standards. The riparian communities are dominated by cottonwood, willow, and herbaceous wetland vegetation. Several areas within the drainage contain high concentrations of Russian olive. The band of vegetation is highly variable in width ranging from eight to 50 feet, but is generally confined to the lower elevations of the alluvial channel corridor and lower elevations that are hydrologically connected.

Based on the amount of channel degradation in portions of the drainage, water regimes appear to range from restricted to irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, and intermittently flooded. As a result, the native grass vegetation community is primarily composed of introduced species and smooth brome is one of the dominant grass species.

The lower reach of Willow Creek near the Englewood Dam contains a vast, emergent cattail wetland. The wetland is described as a palustrine emergent wetland. However, the primary wetland vegetation is a dense monoculture of cattails interspersed with sedges and bulrushes. Some dense pockets of riparian scrub/shrub (sandbar willow) were present in the higher elevations of the reservoir. An illustration of wetland and habitat inventory in Willow Creek is given on Figures E-3 and E-4 in Appendix E.

IV. Identification of Problem Areas

Introduction

The channels within the drainage basins have been impacted severely by urbanization. Often the channel corridors have been improved to be landscaped linear parks and are maintained regularly. Multiple roadway crossings of the drainages have accompanied the channel stabilization that has occurred with urbanization. Over time changes in the watershed as well as local agency criteria has resulted in existing drainage infrastructure that no longer meets the standards set forth by the governing agencies. The drainages were evaluated to determine those areas that are in need of improvement due to failure, or because the infrastructure does not meet current criteria. The evaluation identified the improvements that would be necessary for the safe conveyance of stormwater flows and the mitigation of existing and potential problems.

Evaluation of Existing Facilities

Existing storm drainage facilities that were identified in the Willow Creek, Little Dry Creek, and Greenwood Gulch Watersheds are included in the hydraulic capacity evaluation (Table 4-1, Roadway Crossings Capacity Analysis). Detailed computations of the hydraulic capacity of culverts are presented in Appendix C-1. To be consistent with the scope and efforts of an OSP, minor stormwater infrastructure was not closely evaluated. If the stormwater infrastructure collected runoff from a basin 130 acres or larger or if the infrastructure was determined important for the study by the stakeholders then it is included in the analysis.

Some detention facilities within the watershed are in place but not under a formalized maintenance program. To be consistent with the OSP scope, detention facilities that are not formalized are not included in the existing model since there is no guarantee that they will perform as intended. If these facilities are formalized, they can be included in the future conditions model. An example could be the detention facilities upstream of Quebec on Greenwood Gulch. When the facilities are formalized and included within the model, capacity requirements are reduced. Further discussion on formalizing existing detention facilities is found in Section V.

Hydraulic analysis of channels was performed to determine approximate 100-year flow depths and velocities to identify reaches that are at risk for damage from a major storm event. Hydraulic capacity of the roadway crossings were also evaluated to determine crossings that are at risk of overtopping during a 10-year and 100-year storm event. Table 4-1, Roadway Crossings Capacity Analysis provides a summary of the roadway crossings that are identified as undersized.

As part of the baseline hydrology study, seven regional detention facilities were modeled and evaluated. Refer to Table B-7, Comparison of Pond Data from Current Study with Design Data for the 100-year storm, Appendix B for a complete summary of detention facilities modeled and a comparison with design data. Due to land use changes and additional tributary area not planned for in the design process, one detention facility experiences overtopping during the 100-year event: the Panorama Park Pond. The design outflow for this pond is 177 cfs. The modeled outflow is 764 cfs, based on the hydrology computed for the upstream basin draining into this pond. The remaining flow (or 587 cfs) overtops onto Yosemite Street during a 100-yr event. This pond outlet has recently been downsized to comply with Arapahoe county pond release rates. However, residents have witnessed road flooding due to the pond overtopping.

Existing Problem Areas

Tables 4-2A to 4-2C, Project Area Description, provide a description of the problem areas identified by channel reach in each watershed. Although the watersheds are generally developed and have improved channels, problem areas exist that will only worsen if left unattended. This is especially the case in the reaches of Willow Creek in Lone Tree where stream buffers have successfully prevented encroachment on the channel. The lack of improvements to the drainages in this more natural corridor has resulted in low flow channel degradation as a result of the steady base flow created by urbanization.

TABLE 4-2A
Problem Area Description in Greenwood Gulch

Watershed	Drainageway	Reach	Problem Description
Greenwood Gulch	Greenwood Gulch	Quebec Street to Monaco Way	Quebec Street crossing is undersized (Figure 4-1)
			Channel bank erosion and head cutting in undeveloped parcel.
Greenwood Gulch	Greenwood Gulch	Monaco Way to Orchard Drive	Monaco Way crossing is undersized
			Concrete encased utility crossing exposed at east end of park, acting as a informal drop structure (Figure 4-2)
			Channel bank erosion in park (Figure 4-3)
Greenwood Gulch	Greenwood Gulch	Orchard Road to Holly Street	Flooding outside of channel banks and onto Orchard Drive, threatening adjacent properties. (Figure 4-4)

FIGURE 4-1
Quebec Street crossing on Greenwood Gulch

FIGURE 4-2
Exposed utility crossing on Greenwood Gulch

FIGURE 4-3
Channel bank erosion, Greenwood Gulch

FIGURE 4-4
Greenwood Gulch portion of channel lacking capacity next to Orchard Drive

TABLE 4-2B
Problem Area Description in Little Dry Creek

Watershed	Drainageway	Reach	Problem Description
Little Dry Creek	Little Dry Creek	I-25 to Yosemite Street	Business park detention pond overtops Yosemite Street
Little Dry Creek	Little Dry Creek	Yosemite Street to Uinta Street	Head cut migrating toward Yosemite culvert outfall
			Xanthia Street crossing is undersized
			Low flow channel erosion downstream of Xanthia
			Neighborhood collection system inadequate, localized flooding as reported by residents in Walnut Hills Neighborhood
Little Dry Creek	Little Dry Creek	Uinta Street to Quebec Street	Uinta Street crossing is undersized
			Spruce Street crossing is undersized
			Channel bank erosion between Uinta and Spruce
			Channel bank erosion downstream of Spruce Street crossing
			Active head cut downstream of Spruce Street
Little Dry Creek	Little Dry Creek	Quebec Street to Arapahoe Road	Quebec Street crossing is undersized (Figure 4-5)
			Degradation of low flow channel throughout reach (Figure 4-6)
			High velocities due to steep channel grade

TABLE 4-2B
Problem Area Description in Little Dry Creek

Watershed	Drainageway	Reach	Problem Description
Little Dry Creek	Little Dry Creek	Arapahoe Road to Holly Dam	Failed check structure upstream of Arapahoe Road (Figure 4-7)
			Krameria Way crossing is undersized
			High velocities in channel upstream of Krameria Way
			Deeply incised and eroded channel banks downstream of Krameria Way in open space (Figure 4-8)

FIGURE 4-5
Undersized culvert crossing at Quebec Street on Little Dry Creek

FIGURE 4-6
Low flow channel degradation, Little Dry Creek

FIGURE 4-7
Failed check structure upstream of Arapahoe Road, Little Dry Creek

FIGURE 4-8
Deeply incised channel and vertical bank erosion, Little Dry Creek downstream of Krameria Way in Holly Dam open space area

TABLE 4-2C
Problem Area Description in Willow Creek

Watershed	Drainageway	Reach	Problem Description
Willow Creek	Willow Creek	Lincoln Avenue. to Yosemite Street	Failing drop structure downstream of Heritage Hills Parkway
			Channel bank erosion at bends throughout reach
Willow Creek	Willow Creek	Yosemite Street to Park Meadows Drive	Low flow channel degradation throughout reach
			Channel bank erosion at bends throughout reach
Willow Creek	Willow Creek	Park Meadows Drive to County Line Road	Low flow channel degradation between C-470 and Park Meadows Drive
			Channel bank erosion at bends between C-470 and Park Meadows Drive (Figure 4-10)
Willow Creek	Willow Creek	County Line Road to Mineral Drive	Channel bank erosion at bends throughout reach (Figure 4-12)
Willow Creek	Willow Creek	Mineral Drive to Quebec Street	Mineral Drive crossing is undersized
			Channel bank erosion at bends throughout reach
Willow Creek	Willow Creek	Quebec Street to Dry Creek Road	Quebec Street crossing is undersized
			Channel bank erosion at bends throughout reach
			Failed drop structure upstream of Dry Creek Road
Willow Creek	Cook Creek	Lincoln Avenue. to Lone Tree Parkway	Channel bank erosion in brief reaches on the golf course

TABLE 4-2C
Problem Area Description in Willow Creek

Watershed	Drainageway	Reach	Problem Description
Willow Creek	Spring Creek	County Line Road to Dry Creek Road	Severe channel bank erosion downstream of Otero Avenue (Figure 4-9)
			Head cutting in channel between Mineral Avenue and Otero Avenue (Figure 4-11)
			Mineral Avenue crossing is undersized
			Localized channel bank erosion downstream of Mineral Avenue
Willow Creek	West Spring Creek	Phillips Avenue to Mineral Avenue	Channel bank erosion throughout the reach
			Collection system in neighborhood upstream of Phillips Avenue is undersized as flooding problems reported by residents
Willow Creek	Fox Hills Tributary	Otero Avenue to Englewood Dam	Head cutting at utility crossing downstream of Otero Avenue.
			Low flow channel degradation upstream of Kettle Avenue.
			Kettle Avenue crossing is undersized
			Channel bank erosion downstream of Dry Creek Road
Willow Creek	East Tributary	Yosemite Street to Rosemary Way	Yosemite Street crossing is under sized
			Willow Way crossing is under sized
			Low flow channel degradation between Rosemary Way and Willow Way (Figure 4-14)

TABLE 4-2C
Problem Area Description in Willow Creek

Watershed	Drainageway	Reach	Problem Description
Willow Creek	East Tributary	Rosemary Way to Quebec Street	Low flow channel degradation upstream of confluence with Willow Creek (Figure 4-13)
			Channel capacity issues, storm flows close to private property as reported by residents

FIGURE 4-9
Severe bank erosion downstream of Otero Avenue on Spring Creek

FIGURE 4-10
Bank erosion at bend along C-470 on Willow Creek

FIGURE 4-11
Low flow channel erosion on Spring Creek

FIGURE 4-12
Channel erosion on Willow Creek

FIGURE 4-13
Exposed irrigation sleeve on East Tributary

FIGURE 4-14
Failing gabion at rundown coupled with bank erosion on East Tributary

TABLE 5-2
Little Dry Creek Alternative Cost Summary

Jurisdiction	Repair Alternative	Conveyance Alternative	Detention Alternative	Combination Alternative
Centennial	$3,337,000	$14,368,000	$7,041,000	$8,381,000
Alternative Total	**$3,337,000**	**$14,368,000**	**$7,041,000**	**$8,381,000**

Willow Creek Watershed

Repair Alternative

The Willow Creek watershed has been significantly urbanized and as a result much of the watershed has been stabilized. Although these past improvements have benefited the watershed, there are multiple locations throughout the watershed that require bank stabilization, grade control, or low flow channel repair. The amounts of repairs that are needed are too extensive to describe in detail, but they are presented in detail in Appendix C-2.

Conveyance Alternative

For the conveyance alternative, the crossings located in Lone Tree and Douglas County provide adequate capacity to convey the 100-year event. The need for increased infrastructure is focused within SEMSWA's jurisdiction in the City of Centennial. The crossings that are proposed to be improved and the stream they are located on are identified below.

- Kettle Avenue – Foxhill Park Tributary – Twin 8-foot by 4-foot CBC
- Quebec Street – Willow Creek – New Triple 14-foot by 10-foot CBC with Existing Twin 14-foot by 10-foot CBC's
- Mineral Drive – Willow Creek – New 48-inch RCP with Existing Twin Arch 10-foot by 20-foot CMPA's
- Mineral Avenue – Spring Creek – New 12-foot by 10-foot CBC with Existing 9-foot by 9-foot CBC
- Yosemite Street – East Tributary – 72-inch RCP

Detention Alternative

The Willow Creek watershed has a number of existing stormwater detention ponds that have easements that allow for future maintenance to occur and protect the ponds from ever being eliminated. These ponds were included in the Baseline Hydrology model. There are a few locations where detention may be provided to help reduce the flows in the drainageway such that the existing infrastructure does not need to be increased in size. Because the infrastructure in some locations is so severely undersized the amount of detention needed within the basin is large. Along with formalizing most of the existing ponds that are not formalized, a 75 acre-foot pond is proposed on Willow Creek in Lone Tree, just south of C-470. Although no crossings are undersized in Lone Tree, this pond will provide benefit to the channel and infrastructure in the City of Centennial. The other large detention facility is located at Willow Creek Park upstream of Mineral Drive in Centennial. In order to eliminate overtopping of Quebec Street, a 140 acre-foot pond is required. This will require coordination with the Cherry Creek School District to use their 10-acre parcel for detention.

Combination Alternative

The combination alternative is similar to the detention alternative, with the exception of utilizing a 42 acre-foot pond at Willow Creek Park in order to eliminate an impact to the Cherry Creek School parcel. This also reduces the size of the required culverts at the Quebec Street crossing to twin 8-foot by 7-foot CBC's in conjunction with the existing structure.

A detailed presentation of the identified improvements for the Willow Creek alternatives can be found in Appendix C-2. A summary of the alternative costs are provided in Table V-3, Willow Creek Alternative Cost Summary.

TABLE 5-3
Willow Creek Alternative Cost Summary

Jurisdiction	Repair Alternative	Conveyance Alternative	Detention Alternative	Combination Alternative
Centennial	$5,990,000	$13,460,000	$9,725,000	$9,319,000
Lone Tree	$4,862,000	$4,862,000	$6,401,000	$6,401,000
Douglas County	$1,419,000	$1,666,000	$1,652,000	$1,652,000
Alternative Total	**$12,270,000**	**$19,988,000**	**$17,778,000**	**$17,620,000**

Recommended Alternative

After review with the Project Sponsors, it was clear that the Repair Alternative would need to be included as an element of any adopted plan. This is consistent with the planning objectives that included repairs as an essential element of all plans. All the remaining alternatives achieved the same objectives – 100-year flood management and the conformance with prevailing local jurisdiction criteria. Therefore, the Recommended Plan was generally selected based on the lowest cost. There were occasional refinements based on insights and evaluations conducted subsequent to the development and evaluation of the individual alternatives.

Greenwood Gulch

The Recommended Alternative for Greenwood Gulch is the same as the Combination Alternative. This alternative includes all of the improvements recommended for the Repair Alternative and it formalizes existing detention storage infrastructure to reduce the level of improvements needed in the watershed. This also includes the improvements that are called out in the approved Verona Estates development plan. Because the existing detention in the watershed is primarily located in Greenwood Village; it is expected that Greenwood Village will obtain the necessary easements and maintenance agreements to formalize the detention. Both Greenwood Village and Centennial will experience benefits from this formalization, including lower infrastructure costs and reduced flooding.

Little Dry Creek

The Recommended Alternative for Little Dry Creek is very similar to the Combination Alternative with the addition of some localized recommended improvements. This alternative includes all of the improvements recommended for the Repair Alternative and it provides a reduction in stream flow and increased water quality by constructing detention in a drainageway that is devoid of stormwater flow controls. The new detention will be limited to property that is owned by SSPRD, such that property acquisition is not required. The detention will reduce the flow rates such that smaller infrastructure improvements are needed as compared to the conveyance alternative.

Willow Creek

The recommended alternative for Willow Creek is most similar to the Combination Alternative. The watershed will benefit significantly from the localized repairs that are called for in the Recommended Alternative. The construction of stormwater detention facilities throughout the watershed will increase the water quality as well as reduce the size of required infrastructure to pass the major storm event.

TABLE 5-4
Recommended Alternative Cost Summary

Jurisdiction	Greenwood Gulch	Little Dry Creek	Willow Creek
Greenwood Village	$388,00	$0	$0
Centennial	$925,000	$8,395,000	$9,567,000
Verona Estates Development	$1,841,000	$0	$0
Lone Tree	$0	$0	$6,401,000
Douglas County	$0	$0	$1,652,000
Alternative Total	**$3,154,000**	**$8,395,000**	**$17,620,000**

VI. Conceptual Design of Outfall Systems

Plan Development Overview

The Project Sponsors identified a Selected Plan based on the recommendations put forth in the Alternatives Evaluation Report. Using this direction, a Conceptual Design was developed that presents a higher level of resolution for each of the elements of the Plan.

The Selected Plan can generally be described as a combination of the Repair Alternative and the Combination Alternative which optimized facility sizing through the use of detention within the watersheds. At the Project Sponsors request, the size of some of the detention facilities was evaluated in more detail in the hopes of finding some additional economies. In addition, in the Willow Creek Watershed, the Project Sponsors requested that several existing stormwater detention facilities be evaluated for inclusion into the Plan in the hopes of further reducing the cost for the rest of the proposed improvements.

In all cases, the Selected Plan is intended to provide protection for floods up to the 100-year flood. This is consistent with the prevailing regulations and criteria adopted by each of the Project Sponsors. Since one clearly stated objective was to comply with the prevailing criteria, no other recurrence intervals were considered. The incorporation of full spectrum sizing practices into all new stormwater detention facilities will provide additional controls for more frequent events without compromising the protection provided during the 100-year event.

Because the improvements identified for each of the three watersheds incorporates the Repair Alternative, specific measures are included that address smaller localized drainage and maintenance problems. Moreover, the generalized recommendations also call for diligent inspections and maintenance of future erosion and scour, further limiting the potential for future nuisance issues transforming into significant problems. In some cases, local systems that collect runoff and deliver it to the outfall system create significant problems within the watershed. In these cases only, the plan identified local collection systems that would address these issues. Other areas were deemed to be outside the scope of this Outfall Systems Planning Study and were not investigated nor were explicit improvements proposed.

Outfall System Plan Description

A conceptual design of the Outfall System was developed from the elements of the Selected Plan supported by the Project Sponsors. This design provides a basis for each of the Project Sponsors to develop more specific implementation strategies, prepare Capital Improvement Program budgets and initiate design and drainage easement acquisition efforts.

Greenwood Gulch Watershed

Greenwood Gulch, through the study area, has seen significant improvements and in general does not require a large amount of repair. In the planned Verona Estates parcel the channel has incised and developed steep channel banks that require stabilization. A head cut has migrated up to the downstream toe of an existing baffle chute drop structure. A grouted boulder drop structure will be installed to stabilize the longitudinal channel slope and stop active head cutting of the channel. The improvements proposed as part of the approved Verona Estates development plan are not included in the recommended alternative. These future improvements, if they are to be constructed, will be at the discretion of the site developer.

The upper portion of the watershed has a significant number of stormwater detention ponds, however there are no defined water quality outlet structures included. Therefore, as a part of this alternative, water quality outlets are recommended.

The proposed formalization of detention ponds includes the 16 acre-feet upstream of Quebec Street and the 8.5 acre-feet of storage on the Orchard Draw tributary north of Greenwood Gulch. With the benefits of this detention accounted for in the watershed, flows are reduced and the existing Quebec Street crossing is adequately sized. The Monaco Way crossing still requires an additional 60" RCP to convey the 100-year event. The detention also reduces peak flow rates such that the channel along Orchard Drive has adequate capacity and does not need to be improved

Little Dry Creek Watershed

Little Dry Creek at the downstream end of the study area flows through the Holly Dam open space. In this reach the channel has become deeply incised and has locations of vertical banks that are actively eroding. Channel repairs and water quality improvements in the Holly Dam open space area are recommended to improve the drainageway. Upstream of Arapahoe Road the channel is experiencing low flow erosion that needs to be repaired to prevent erosion of the channel overbanks and side slopes. The remaining reaches in Little Dry Creek are experiencing localized erosion that needs to be repaired.

The Holly Dam was designed to provide a significant amount of stormwater detention to protect the area downstream from flooding. Upstream of this facility there is very little detention, and very little opportunity for detention. Because of the limited space available for detention many of the conveyance improvements are still required. However, with the detention that has been identified, smaller infrastructure is required. The most significant detention pond proposed is upstream of the Spruce Street crossing. The proposed pond will fit entirely on SSPRD property and coordination with the School District is not required. This results in a 26 acre-foot pond. Utilizing this pond and formalizing the existing 6 acre-foot pond upstream of Yosemite Street, the required improvements to roadway crossings are reduced to the following:

- Krameria Way – Twin 8-foot by 7-foot CBC
- Quebec Street – New 48-inch RCP and Existing CBC's
- Spruce Street – New 72-inch RCP and Existing Twin 66-inch RCP
- Uinta Street – Twin 8-foot by 8-foot CBC
- Xanthia Street – Existing 60-inch RCP and New 18-inch RCP
- Yosemite Street – 60-inch RCP

A new storm sewer installed down Yosemite will divert flows from the commercial development that is located due south of the Walnut Hills Neighborhood. The new, 2,100 foot long, storm sewer will connect to an existing detention pond and direct flows to Little Dry Creek. This will prevent surcharging of the existing storm sewer within the Walnut Hills Neighborhood and eliminate flooding problems.

Willow Creek Watershed

The Willow Creek watershed has been significantly urbanized and as a result much of the watershed has been stabilized. Although these past improvements have benefited the watershed, there are multiple locations throughout the watershed that require bank stabilization, grade control, or low flow channel repair.

The Willow Creek watershed has a number of existing stormwater detention ponds that have easements that allow for future maintenance to occur and protect the ponds from ever being eliminated. These ponds were included in the Baseline Hydrology model and are assumed to remain in place as part of the Selected Plan. A number of other ponds were not included in the baseline hydrology because no formal easements exist. However, considerable benefit accrues from flow attenuation through these ponds. The Selected Plan calls for the formalization of a number of these ponds to reduce the flows in the drainageway such that the existing infrastructure does not need to be increased in size. Because the infrastructure in some locations is so severely undersized the amount of detention needed within the basin is larger than can be provided merely by formalizing existing detention. An additional 9 acre-foot pond is proposed on Willow Creek in Lone Tree, just south of C-470. Although no crossings are undersized in Lone Tree, this pond will provide benefit to the channel and infrastructure in the City of Centennial. Another large detention facility is located at Willow Creek Park upstream of Mineral Drive in Centennial. In order to eliminate overtopping of Quebec Street, a 39 acre-foot pond is required in addition to enlarging the crossing to twin 8-foot by 7-foot CBC's.

General Recommendations

In addition to the specific elements of the Selected Plan, a number of general recommendations are offered for Project Sponsor consideration. These recommendations are intended to overlay the specific elements of the Selected Plan. In most cases, these recommendations recognize current practices that should be formalized and imposed across the watershed.

Each jurisdiction having review or maintenance responsibility should take steps to stabilize all major waterways when watersheds within their jurisdiction urbanize, rehabilitate existing degraded reaches of the waterways and their tributaries, and aggressively control erosion and sediment transport during construction activities.

Project Sponsors and any other jurisdiction having land use control powers in any of the watersheds included in this study should require new land development, significant redevelopment, and publicly funded projects to provide, to the maximum extent practicable, runoff volume control practices (i.e., minimize directly connected impervious areas and employ infiltrating BMPs) whenever site conditions permit. They should also provide a Water Quality Capture Volume (WQCV) or Full Spectrum Detention Volume as recommended in the USDCM – Volume 3, after accounting for volume reductions achieved using volume control practices as recommended above.

Project Sponsors and any other jurisdiction having land use control powers in any of the watersheds included in this study should, whenever land use changes result in impervious ratios that exceed the projections identified in this Report, take steps to limit further increases in stormwater runoff through the use of additional on-site detention, infiltrating BMPs, Full Spectrum detention facilities, and WQCV BMPs, thereby reducing the runoff rates, volumes and future damage potential to the levels reported in this Planning Study.

Project Sponsors and any other jurisdiction having land use control powers in any of the watersheds included in this study should continue to implement their floodplain management regulations, including regulation of the 100-year floodway and floodplain and should adopt a policy, if not already done so, of reserving the defined floodplains as open spaces to the maximum extent possible and that at least 1-foot freeboard be provided for the lowest floor above the 100-year flood elevation shown on the latest flood hazard area delineation or FIRM maps for all human occupied structures built adjacent to, or within, the defined 100-year floodplains. These Jurisdictions should continue to participate in FEMA's flood insurance Community Rating System and public education programs.

Prioritization and Phasing Plan

Elements of the Selected Plan should be built in their entirety if possible. However, it is understood that municipal budgets often preclude the concurrent implementation of improvements. In fact, fiscal realities suggest that some lower priority improvements may not be constructed unless channel conditions deteriorate further. Recognizing that implementation may need to be phased, the following Priorities are proposed:

1. Formalize identified stormwater detention facilities. The formalization of existing detention can be done with minimal capital investment. This effort is largely administrative, requiring dedicated and unrestricted municipal maintenance access or formalized agreements providing reasonable assurances that maintenance will be provided in perpetuity. The flow reduction benefits associated with those facilities are already seen in the evaluations but can not be formally recognized without these formal agreements. Should any of these identified facilities been breached or otherwise rendered inoperable, the flows in the watershed would increase immediately with a resulting increase in flood hazard.

   Because an objective of this study was to meet prevailing design standards for all facilities, the formalization of these detention facilities will generally require the installation of a water quality outlet that is designed to drain the WQCV over a 40 hour period. In addition to making the facilities eligible for District maintenance funding, the enhanced water quality resulting for the extended detention will provide benefits to the downstream channels. Full spectrum detention is not considered for retrofitting or formalizing existing facilities but is considered for new facilities as discussed in item 3 below.

2. Stabilize high priority reaches of channel – Many areas along the study reaches are severely degraded. These channels have the potential to cause significant damage to public infrastructure such as utilities or trails and roadways and to encroach into private property adjoining the channels. Repairs, bank protection, channel grade controls and other measures to arrest uncontrolled channel degradation and meander should be implemented as priority two improvements. Table 6-1, Stabilization Priorities, presents the areas that have been indentified as needing the most urgent attention.

TABLE 6-1
Stabilization Priorities

Watershed	Tributary	Station	Proposed Improvements
Greenwood Gulch	Main Stem	30+00	Sloping Grouted Boulder Drop Structure to protect existing utility crossing
Little Dry Creek	Main Stem	22+00	Bank stabilization downstream of Krameria Way outfall to protect existing trail and prevent channel migration toward Arapahoe Road
Willow Creek	Main Stem	130+00	Bank stabilization adjacent to State Highway C-470. The channel has migrated into the Highway ROW and is approaching the road with vertical banks in excess of 20-feet.

3. Construct new stormwater detention facilities – The analyses conducted for the planning study indicate a broad benefit from increased stormwater detention in the watershed. These improvements provide clear local benefits by reducing flows in the immediate vicinity of the structures. They also influence flows for quite some distance downstream, often easing the potential flood hazard along several reaches downstream. These improvements were generally shown to provide a greater benefit for comparable investment than localized conveyance improvements. Moreover, the inclusion of EURV, which is known as Full Spectrum storage, has significant water quality benefits and also helps to replicate pre-development runoff hydrographs, further reducing downstream impacts.

4. The final recommended priority across the watershed is the localized construction of improved roadway crossings. These bridge or culvert replacements or enlargements do have the potential to significantly improve flood hazard in the local area but have limited broad impact. Decisions regarding the implementation of these improvements will need to be made on a case-by-case basis and should reflect local needs and hazards. In many cases, the proposed recommendations in this plan reflect the Project Sponsors' desire to have all facilities meet District or local community design requirements. In many cases, the underlying criteria were not being met but no explicit flood hazard was identified. In these cases, the tangible benefit is limited and is generally only improved access during flood emergencies. Nevertheless, this is an important standard in the eyes of the Project Sponsors and facilities should be upgraded when funds are available.

Cost Estimate

Unit costs for improvements were taken from the Colorado Department of Transportation (CDOT) 2008 Cost Data, UDFCD Bid Tabs, past UDFCD OSPs, and experience with other projects. In situations where the project elements could be assembled for completed work elements (e.g. box culverts in place) the individual unit prices were combined and price estimates in this report were based on a more simplified in place unit cost.

All costs are presented in 2009 dollar values and are shown in Table 6-2. Where maintenance costs are presented, the costs reflect full life cycle costs over the 50-year planning horizon. A discount rate of 3.5 percent was used for operation and maintenance assuming a 50-year period of maintaining the facilities. The discount factor for this rate and period is 23.46.

Earthwork quantities were computed for each improvement identified in a project reach. Values include excavation and backfill of material without a separate haul expense. Most improvements are sufficiently localized to not demand specialized haul equipment. When material is to be imported, a cost associated with material purchase, haul and placement is included. When excess materials are expected that can not be wasted on site, off-site haul was estimated to a local waste area. A haul of less than 10 miles was assumed.

Enhancement of existing ponds to incorporate water quality outlet structures is proposed in several locations. The construction of a water quality outlet includes the construction of an orifice plate riser, outlet structure with overflows and all appurtenances. The replacement of the existing outlet pipe and significant modifications to pond grading are not anticipated. When new detention is required, a more generic approach to facility cost estimating is used. In this case, rather than develop site specific quantities for earthwork, infrastructure, access and other appurtenances, past project costs were used to develop a lump sum estimate. This estimate was developed using over one-half dozen recent pond construction projects of various sizes. All costs were updated to 2009 costs to provide a consistent basis for estimation. The completed facility construction cost was plotted against facility volume and a curve fit to the data points. The resulting curve was used for the estimation of new construction for this project.

Low flow channel repair costs were estimated based on a typical cross section where low flow banks needed to be laid back and replaced with buried soil riprap. Here, earthwork quantities and a layer of Type M buried riprap extending beneath the channel invert were priced, along with all appurtenant work, to develop a cost per square yard. In some cases, the existing low flow channel was lined with boulders that needed repair. Here, rather than using buried soil riprap, boulders were assumed to line the channel. The extent of embedment was less than for a sloping bank but did conform with the existing channel configuration.

Costs for grouted boulder drops are based on a square yard quantity that includes rock, grout, minor earthwork beyond that to establish general stable channel grade and all labor and equipment necessary to complete the installation. Costs for these facilities are developed using bid costs for a variety of installed structures and developing an average cost per square yard of surface area. Soil riprap bank protection is identified where the channel is actively eroding. The quantity of material to be used to stabilize the bank was estimated for each specific area of repair. Costs for riprap include a minimum size of Type M riprap with a thickness of two times the D_{50}. Bedding, surface preparation and placement are included in the unit cost. Earthwork to provide a stable slope for riprap placement is not included in this cost. Rather, those quantities are estimated separately and included in the earthwork estimate.

Costs for box culverts and concrete pipes were based on recent bid tabulations for CDOT projects. The box culvert costs are based on a price per square foot of culvert opening per linear foot of structure. Common pipe sizes are estimated based on a cost per linear foot. In all cases, surface restoration costs such as pavement patching, revegetation or minor earthwork are included. Other appurtenances such as manholes and inlets, when they are minor elements of the work, are included in the unit costs for pipe or box culvert. When the appurtenances are a significant element of the work, such as in the case where collection system enhancements are proposed, the cost of inlets, manholes, piping and outfall system stabilization are bundled to develop a lump sum cost for the improvements. Again, the cost of pavement repairs or other surface restoration is included. There are several cases where outfalls are to be stabilized with dumped

riprap. In these cases, a lump sum cost based on a minimum size of Type M riprap with a thickness of two times the D_{50} is used to develop costs.

Drainage easements were identified only in those locations where improvements are recommended and ownership is private and not part of an association or metro district. These quantities were estimated to allow the construction of improvements and to provide permanent access for the maintenance of facilities. It is assumed that for all improvements planned on property owned by a homeowners association (HOA) or metro district, the required easements will be dedicated without charge to the jurisdiction. As such, while a unit price is presented, the improvement estimates do not include costs.

All maintenance costs are based on estimates provided by UDFCD. Channel maintenance costs are based on a cost of $2.00 per year per linear foot of channel. Using the discount rate of 3.5 percent over the 50 year life cycle yields a present worth factor of 23.46 and a unit cost of approximately $47/linear foot. Pond maintenance costs are estimated based on a cost of $100 per year per acre-foot of storage volume and result in a cost of $2,350/acre foot.

Costs for utility relocation are based on 5 percent of the estimated cost of drainage infrastructure. This cost reflects small utility lines such as service laterals, small water distribution system lines and power, telecommunication and irrigation facilities that may be disrupted during construction. Large main lines that will require specialized design and treatment will be handled uniquely.

Similarly, mobilization is handled as 5 percent factor added to the total construction cost that includes drainage infrastructure cost as well as the utility relocation cost to develop a construction sub-total. A contingency of 30 percent is applied that reflects the uncertainty associated with the conceptual stage of the project design. This value is based on 30 percent of the construction sub-total and, when added to the construction sub-total, represents the Construction Cost. Engineering, administrative and legal costs are assumed to be 20 percent of the Construction Cost. The combined total of these costs represents the Project Implementation Cost estimate. Maintenance costs are added to the Project Implementation Cost for the Total Project Life Cycle Cost. Only after all the miscellaneous costs, contingencies and administrative costs been added to develop the Implementation Cost are maintenance costs included to develop the Total Project Life Cycle Cost.

TABLE 6-2
Unit Costs

Item	Unit	Unit Cost
Earthwork (Balance on Site)	CY	$8.00
Earthwork (Haul in or off Site)	CY	$20.00
Water Quality Outlet Structure	Each	$20,000
Stormwater Detention Pond	Acre-feet	9000*AF+40000
Low flow Channel Repair	LF	$100
Low flow Channel Boulder Lining	LF	$150
Grouted Sloping Boulder Drop Structure	SY	$300

TABLE 6-2
Unit Costs

Item	Unit	Unit Cost
Soil Riprap	CY	$65
Concrete Box Culvert	SF*LF*	$25
18” and 24” RCP	LF	$200
42” RCP	LF	$400
48” RCP	LF	$530
60” RCP	LF	$600
66” RCP	LF	$730
72” RCP	LF	$800
Collection System Improvements	LS	$50,000
Outfall Protection	Each	$25,000
Revegetation	Acre	$5,000
Constructed Wetland	Acre	$50,000
Drainage Easement Value	SF	$2.30
Channel Operation & Maintenance (50-years)	LF	$47
Pond Operation & Maintenance (50-years)	Acre-feet	$2,350
Utility Relocation Costs	Percent	5% of Drainageway Cost
Mobilization	Percent	5% of Drainageway Cost
Contingency	Percent	30% of Total Construction Cost
Engineering, Administrative, and Legal Services	Percent	20% of Total Construction Cost

*[$/(SF*LF)]*[LF of Pipe]*[Area of Pipe Opening (SF)] = $

Water Quality Impacts

The elements identified in the Selected Plan have a beneficial impact on water quality. In combination, the proposed improvements will enhance water quality by stabilizing eroding channels, providing water quality detention in existing stormwater detention ponds, and constructing additional stormwater detention that will also include water quality controls. Since many of the water quality issues facing urban streams such as Greenwood Gulch, Little Dry Creek and Willow Creek are the direct result of high sediment levels, any controls that reduce suspended solids will generally have a beneficial impact on water quality.

The repairs to degrading channel reaches identified as part of the Selected Plan will have an immediate benefit to water quality along all the streams by reducing the amount of sediment being supplied to the streams. Many of the water quality concerns identified in the study reaches revolve around the high levels

of sediment originating from eroding banks and head cuts along the channel invert. The bank protection measures and grade controls will reduce the potential for future erosion thereby reducing the sediment source. Because there will be less sediment mobilized from these unstable areas, less sediment will be conveyed and deposited downstream.

These channel and bed stabilization measures will also include an extensive revegetation effort. Vegetated channels and channel banks provide additional stabilizing functions that reduce erosion but they also provide an important filtration function. As water flows across these surfaces there is often a filtering affect and some pollutants are trapped in the vegetative mass and removed from the stream.

The formalization of existing stormwater detention will include upgrades to outlets to provide water quality capture volume and a 40-hour release. This will allow many pollutants being carried by the stream to be deposited in the ponds and not in the downstream channels. The resulting reduction in pollutants that adhere to the suspended particles reduces the concentrations in the downstream channels.

New stormwater detention will have similar design features that assure an adequate storage time to reduce downstream peak flows and to allow large suspended sediment particles to settle. The settling function is similar to that of the formalized detention. New detention brings an added water quality benefit by reducing flow rates. The erosive power of water is a direct function of flow rate. Since these detention ponds reduce downstream flow rates they also reduce the erosion and sediment carrying potential. As such, there is less potential for large sediment loads to be carried which results in enhanced water quality.

Operation and Maintenance

Most of the channels within the Study Area have a formal trail network that is used jointly for recreational and maintenance access. The ability to provide fairly direct maintenance access to the channel greatly enhances the efficiency of maintenance activities that will be required to assure the long term performance of the existing and proposed facilities.

Periodic inspections of all channels and stormwater detention ponds are essential to assure their long term function as intended. Inspections should monitor the condition of the channel invert and banks looking for areas of excessive erosion or scour that may pose a threat to surrounding properties or uncontrolled vegetative growth that could choke channel capacity. When such conditions are observed, actions should be taken to restore the channel to its intended capacity and alignment. Similar monitoring of stormwater detention ponds is necessary to assure that outlet works continue to function as designed and that accumulations of sediment don't reduce the necessary storage capacity. If either condition is observed, repair or dredging should be initiated to assure continued satisfactory performance.

Another function of the periodic inspections is to identify conditions that would require some of the lower priority repairs to be initiated. Frequent street overtopping, areas of high flow that cause new erosion or headcutting, or places where existing infrastructure is being endangered should all be noted and necessary improvements designed and implemented.

Routine operation and maintenance activities are necessary for all drainage infrastructure. In addition to the inspections described earlier, other activities should be planned and executed periodically. This includes mowing of channels and detention ponds. These activities assure continued performance in accordance with design objectives and also maintain the aesthetic integrity of these improvements. Sediment removal is a normal part of the operation of ponds. As sediment accumulates the pond capacity is diminished. Periodic removal assures that the ponds will function in accordance with their design intent. Trash and debris frequently accumulates in drainageways and should be removed periodically. This function is often done concurrently with mowing. Finally, natural drainage systems are dynamic and periodically adjust to flow conditions. These adjustments may be minor erosion or meanders that don't constitute failure but, if left unaddressed, may create future problems. Normal maintenance activities include minor repairs to address localized issues that may not impair function but could cause long term problems.

Environmental and Safety Assessment

Several areas of important environmental amenities were identified. These were described in some detail in Section II of this report. These areas have been preserved as part of the Selected Plan. Their function remains intact. In fact, many of the proposed improvements are intended to enhance other areas that are currently only marginally functional. By stabilizing and providing revegetation along the banks, new and enhanced habitat areas are provided that supplement those that already exist. In many areas, these improvements serve to extend existing habitat areas and provide a more continuous corridor of habitat to provide unencumbered movement of animals along the riparian corridor.

Wetland areas within the watersheds are fairly limited. The proposed improvements do not explicitly intend to create new wetland areas. However, the channel stabilization improvements are likely to have a beneficial impact on existing wetland areas by reducing the amount of sediment that moves along the streams. The lower sediment concentrations are less likely to deposit in the existing wetland areas where flow velocities slow, thereby reducing the potential of sediment choking the wetlands. The added detention ponds also attenuate the runoff hydrograph and may more closely replicate natural flow conditions. These conditions are generally more favorable for wetlands than the more common urban cycle of very high flows for short durations and very long periods of very low or zero flow.

The proposed improvements in the Selected Plan will enhance safety in the watershed in several ways. The most obvious is the reduction in flood hazard that results from a well thought out and coordinated flood control infrastructure. The channel stabilization, detention pond and conveyance improvements proposed work in combination to provide a higher level of protection from flooding up to and including the 100-year recurrence interval. Public facilities and roadways will be less subject to impact as a result of these improvements.

The proposed improvements also enhance public safety during times when floods are not occurring. Stabilizing channel banks results in more gently sloped banks along many of the streams in the Study Area. These more stable slopes pose a smaller fall hazard to people walking along the trails that line many of the channels. This allows the public to safely travel these corridors and to have more frequent access to the water.

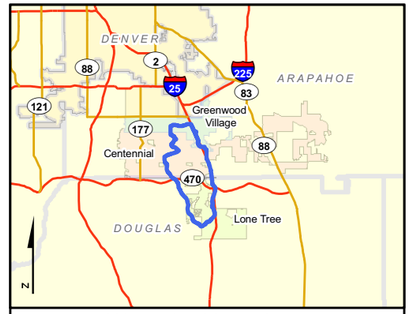
Outfall Systems Plan Drawings

Plan and profile drawings have been developed that show the proposed improvements to the study areas to achieve the goals identified by the project sponsors. The drawings have been included in Appendix F of

this report with corresponding commentary sheets. Table 6-3 provides a summary of the costs developed for the conceptual design.

APPENDIX B

Hydrologic Analysis



Watershed Location

Willow Creek, Little Dry Creek, and Greenwood Gulch Outfall Systems Planning Study

Legend

- Studied Stream Reaches
- Non Studied Stream Reaches
- Sub Basins
- County Boundary
- SEMSWA Service Area
- SSPRD Boundary
- Municipalities

Future Land Use, % Impervious

- Commercial, 95%
- Future Commercial, 75%
- Highways, 98%
- Industrial, 85%
- Open Space, 5%
- Single Family, 48%
- Large Lot (R-2 to 2.5), 28%
- Multi Family, 75%

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WILLOW CREEK, LITTLE DRY CREEK, AND GREENWOOD GULCH FUTURE LAND USE FIGURE B-2

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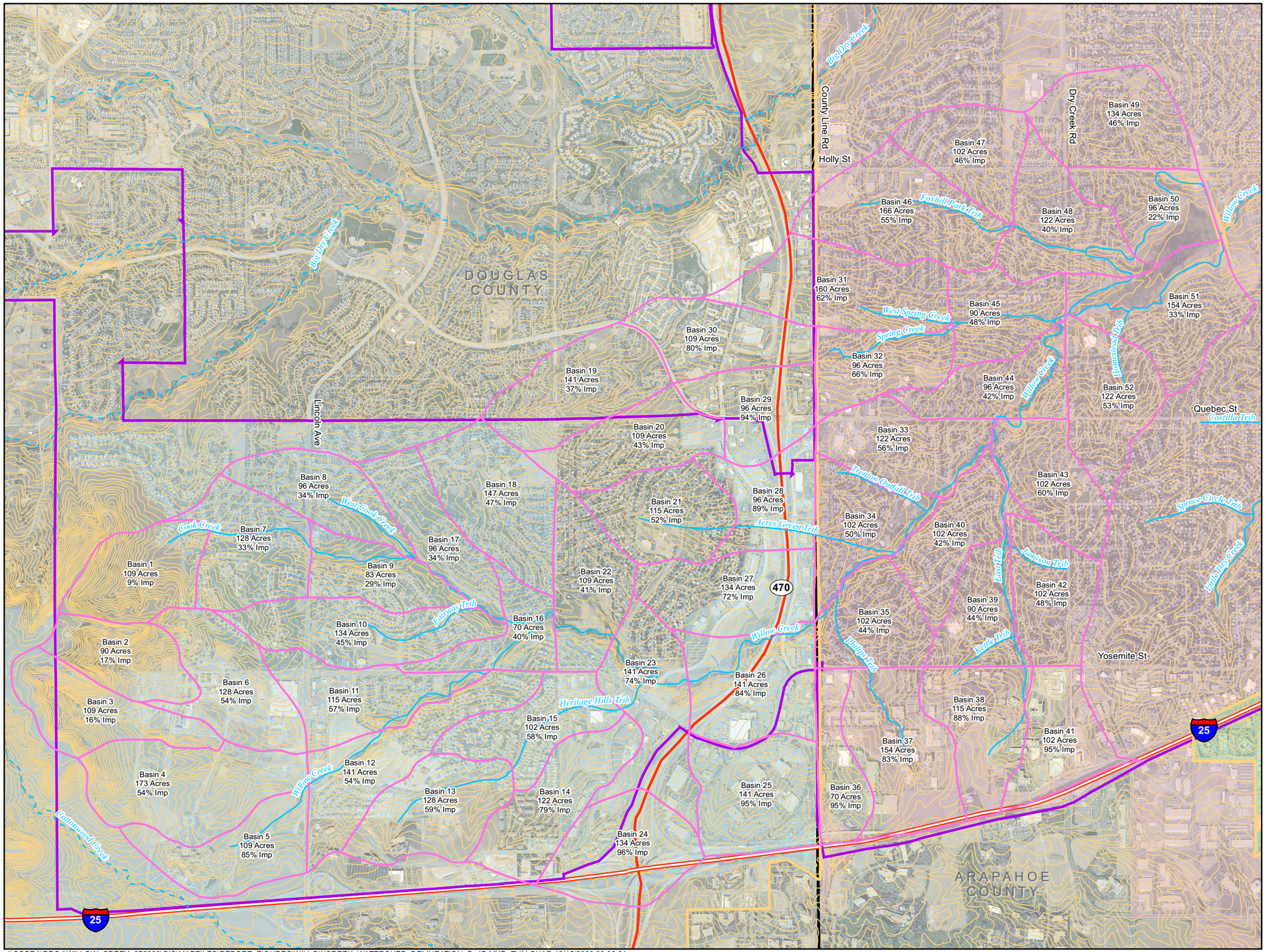

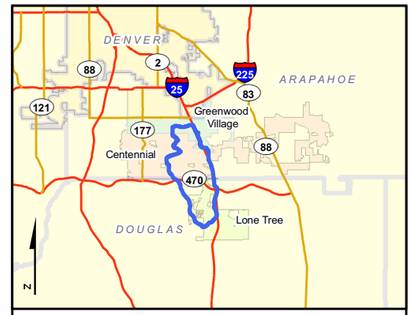

Watershed Location

Willow Creek, Litte Dry Creek, and Greenwood Gulch Outfall Systems Planning Study

Legend

- Studied Stream Reaches
- Non Studied Streams Reaches
- USGS 10ft Contours
- SEMSWA Service Area
- SSPRD Boundary
- County Boundary

Watershed

- Willow Creek

Municipalities

- Centennial
- Greenwood Village
- Lone Tree

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WILLOW CREEK BASIN DELINEATION FIGURE B-4B

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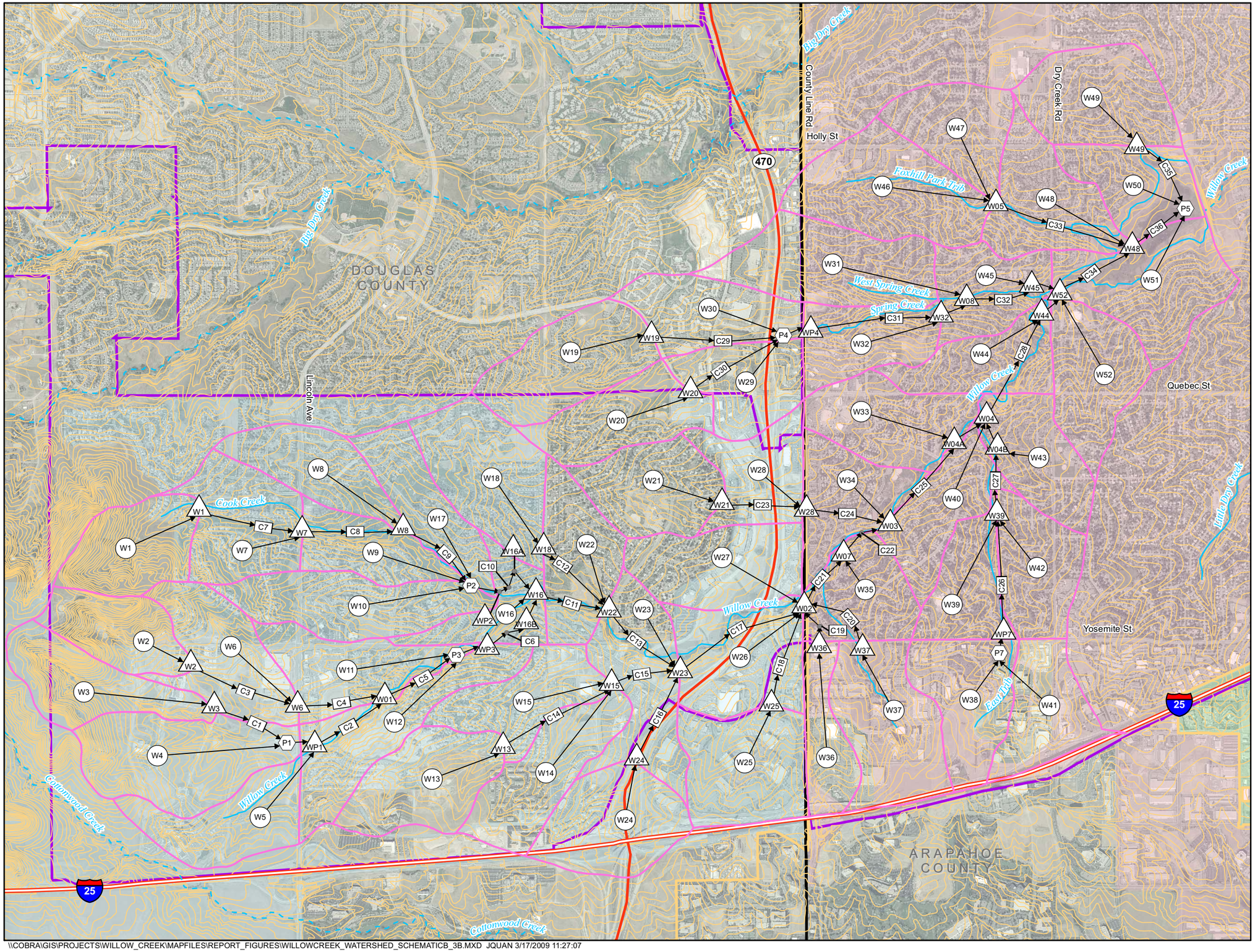

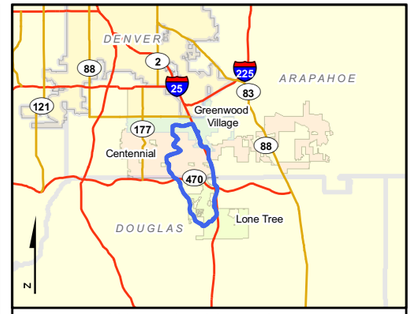

Watershed Location

Willow Creek, Litte Dry Creek, and Greenwood Gulch Outfall Systems Planning Study

Legend

- Studied Stream Reaches
- Non Studied Stream Reaches
- USGS 10ft Contours
- County Boundary
- SEMSWA Service Area
- SSPRD Boundary

Watershed

- Willow Creek

Municipalities

- Centennial
- Greenwood Village
- Lone Tree

- Conveyance Element
- Pond
- Flow Junction
- Flow Direction
- Basin

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WILLOW CREEK MODEL SCHEMATIC FIGURE B-6B

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Table B-1

Summary of CUHP Input Parameters (Version 1.3.1)

								Depression Storage		Horton's Infiltration Parameters			DCIA Level and Fractions		
Catchment Name/ID	Basin	Area in (sq.mi.)	Area (acres)	Dist. to Centroid (miles)	Length (miles)	Slope (ft./ft.)	Pecent Imperv.	Pervious (inches)	Imperv. (inches)	Initial Rate (in./hr.)	Final Rate (in.hr.)	Decay Coeff. (1/sec.)	DCIA Level	Dir. Con'ct Imerv. Fraction	Receiv. Perv. Fraction
1	Willow Creek	0.170	109	0.312	0.685	0.048	9.1	0.35	0.10	3.00	0.50	0.0018	1.00	0.15	0.11
2	Willow Creek	0.140	90	0.381	0.686	0.050	17.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.24	0.17
3	Willow Creek	0.170	109	0.530	0.919	0.049	15.8	0.35	0.10	3.00	0.50	0.0018	1.00	0.23	0.16
4	Willow Creek	0.270	173	0.502	1.035	0.040	53.8	0.35	0.10	3.00	0.50	0.0018	1.00	0.65	0.29
5	Willow Creek	0.170	109	0.385	0.753	0.038	84.8	0.35	0.10	3.00	0.50	0.0018	1.00	0.98	0.34
6	Willow Creek	0.200	128	0.371	0.789	0.045	53.5	0.35	0.10	3.00	0.50	0.0018	1.00	0.66	0.31
7	Willow Creek	0.200	128	0.239	0.548	0.048	32.5	0.35	0.10	3.00	0.50	0.0018	1.00	0.42	0.28
8	Willow Creek	0.150	96	0.466	0.889	0.035	34.4	0.35	0.10	3.00	0.50	0.0018	1.00	0.43	0.28
9	Willow Creek	0.130	83	0.496	0.758	0.025	28.6	0.35	0.10	3.00	0.50	0.0018	1.00	0.37	0.26
10	Willow Creek	0.210	134	0.628	1.130	0.032	44.8	0.35	0.10	3.00	0.50	0.0018	1.00	0.55	0.31
11	Willow Creek	0.180	115	0.594	1.068	0.037	57.3	0.35	0.10	3.00	0.50	0.0018	1.00	0.66	0.31
12	Willow Creek	0.220	141	0.571	1.065	0.034	53.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.64	0.36
13	Willow Creek	0.200	128	0.368	0.799	0.036	58.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.72	0.36
14	Willow Creek	0.190	122	0.473	0.895	0.032	78.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.90	0.33
15	Willow Creek	0.160	102	0.382	0.845	0.029	57.8	0.35	0.10	3.00	0.50	0.0018	1.00	0.67	0.36
16	Willow Creek	0.110	70	0.208	0.697	0.027	39.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.49	0.31
17	Willow Creek	0.150	96	0.533	0.889	0.023	34.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.44	0.30
18	Willow Creek	0.230	147	0.443	0.831	0.030	46.6	0.35	0.10	3.00	0.50	0.0018	1.00	0.57	0.35
19	Willow Creek	0.220	141	0.379	0.786	0.040	37.1	0.35	0.10	3.00	0.50	0.0018	1.00	0.47	0.32
20	Willow Creek	0.170	109	0.297	0.726	0.037	43.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.52	0.31
21	Willow Creek	0.180	115	0.289	0.664	0.037	51.6	0.35	0.10	3.00	0.50	0.0018	1.00	0.62	0.38
22	Willow Creek	0.170	109	0.249	0.696	0.038	41.0	0.35	0.10	3.00	0.50	0.0018	1.00	0.53	0.30
23	Willow Creek	0.220	141	0.124	0.653	0.031	73.5	0.35	0.10	3.00	0.50	0.0018	1.00	0.80	0.34
24	Willow Creek	0.210	134	0.199	0.610	0.037	96.5	0.35	0.10	3.00	0.50	0.0018	1.00	1.00	0.39
25	Willow Creek	0.220	141	0.286	0.608	0.036	95.3	0.35	0.10	3.00	0.50	0.0018	1.00	1.00	0.38
26	Willow Creek	0.220	141	0.413	0.779	0.018	83.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.88	0.35
27	Willow Creek	0.210	134	0.395	0.788	0.035	72.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.82	0.37
28	Willow Creek	0.150	96	0.236	0.584	0.032	88.6	0.35	0.10	3.00	0.50	0.0018	1.00	0.94	0.39
29	Willow Creek	0.150	96	0.314	0.571	0.033	94.4	0.35	0.10	3.00	0.50	0.0018	1.00	0.99	0.38
30	Willow Creek	0.170	109	0.381	0.790	0.029	79.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.94	0.32
31	Willow Creek	0.250	160	0.447	1.025	0.030	61.9	0.35	0.10	3.00	0.50	0.0018	1.00	0.71	0.37
32	Willow Creek	0.150	96	0.371	0.760	0.030	65.8	0.35	0.10	3.00	0.50	0.0018	1.00	0.76	0.34
33	Willow Creek	0.190	122	0.599	0.944	0.026	55.5	0.35	0.10	3.00	0.50	0.0018	1.00	0.64	0.34
34	Willow Creek	0.160	102	0.395	0.751	0.028	50.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.64	0.28
35	Willow Creek	0.160	102	0.510	0.851	0.024	44.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.55	0.36
36	Willow Creek	0.110	70	0.400	0.717	0.017	94.6	0.35	0.10	3.00	0.50	0.0018	1.00	1.00	0.38
37	Willow Creek	0.240	154	0.374	0.749	0.023	82.6	0.35	0.10	3.00	0.50	0.0018	1.00	0.92	0.33
38	Willow Creek	0.180	115	0.400	0.697	0.027	87.7	0.35	0.10	3.00	0.50	0.0018	1.00	0.98	0.36
39	Willow Creek	0.140	90	0.466	0.796	0.033	44.2	0.35	0.10	3.00	0.50	0.0018	1.00	0.54	0.34
40	Willow Creek	0.160	102	0.397	0.967	0.026	41.6	0.35	0.10	3.00	0.50	0.0018	1.00	0.53	0.34
41	Willow Creek	0.160	102	0.368	0.631	0.029	95.0	0.35	0.10	3.00	0.50	0.0018	1.00	1.00	0.38
42	Willow Creek	0.160	102	0.332	0.718	0.026	47.9	0.35	0.10	3.00	0.50	0.0018	1.00	0.60	0.36
43	Willow Creek	0.160	102	0.420	0.737	0.033	60.0	0.35	0.10	3.00	0.50	0.0018	1.00	0.75	0.34
44	Willow Creek	0.150	96	0.607	1.082	0.025	41.5	0.35	0.10	3.00	0.50	0.0018	1.00	0.52	0.30

Recommended Alternative Commentary Page 7

Willow Creek - Willow Creek Part to Park Meadows Drive (Station 130+00 to Station 200+00)

Acres Green Tributary

Reach Description - Willow Creek, UDFCD Drainageway ID 5402, has the largest contributing area to the downstream project limit of Holly Street. In general, flow in the Willow Creek watershed is from the south to the north and has approximately 15.4 miles of stream length including tributaries. The Willow Creek drainageway includes a series of tributary streams that make up the stream network for the watershed. The channel continues toward the northwest and parallels the north side of the Willow Creek Park. The channel through this reach is similar to the channel immediately upstream with large trees and mature vegetation. Willow Creek crosses Mineral Drive and flows toward the Quebec Street crossing and the confluence with the East Tributary. The reach between Mineral Drive and Quebec Street also has very mature vegetation and large trees. There are locations of bank erosion mostly located at the outside of channel bends. The channel grade has been stabilized by a large concrete baffle shoot drop structure located downstream of the confluence with the East Tributary.

The East Tributary to Willow Creek flows from east to west and originates in the Panorama Park office park. The runoff from the commercial area is collected in the Panorama Park stormwater detention pond just east of Yosemite Street. The pond discharges to the East Tributary into a linear park that is bordered by single family homes. For much of the channel between Yosemite and Rosemary Way the low flow channel is boulder lined, and the overbanks are maintained turf grass. Through this reach there are multiple pedestrian crossings of the channel as well as grouted boulder drop structures. Downstream of the Rosemary Way crossing the channel parallels Jamison Drive and is no longer in a linear park. The channel between the confluence with the main stem of Willow Creek and Rosemary Way is trapezoidal in shape with an approximately 8' wide bottom and native grass lined channel banks. There are a few drop structures that are providing channel grade control through this reach.

Willow Creek Combination Alternative Improvements - Channel bank stabilization is required in multiple locations of Willow Creek, most frequently along the outside of channel bends, the existing grade control structures . Sediment deposition needs to be removed at the outfall of the County Line box culvert. Outfall protection is required at the pipe outfall from the eastern collection system just upstream of County Line Road. Provide Outlet Protection at Station 155+00 and construct a detention pond south of C-470 to detain 75 acre-ft.

Philips Tributary Combination Alternative Improvements - Formalize detention pond east of Yosemite St to detain 8 acre-feet.

Acres Green Tributary Combination Alternative Improvements - Perform a collection system repair at Phillips Circle to increase the capacity.

Drainageway	Jurisdiction	Item	Unit	Quantity	Unit Cost	Total Cost	Reach Cost
Acres Green Tributary	Centennial/SEMSWA	Increase Collection System Capacity	LS	1	$ 50,000.00	$ 50,000	
		Mobilization Costs (5% of Drainageway Costs)				$ 2,500	
		Utility Costs (5% of Drainageway Costs)				$ 2,500	
		Contingency (30%)				$ 16,500	
		Engineering, Admin, Legal Services (20%)				$ 11,000	**$ 82,500**
Philips Tributary	Centennial/SEMSWA	Water Quality Outlet Structure	EA	1	$ 20,000.00	$ 20,000	
		Mobilization Costs (5% of Drainageway Costs)				$ 1,000	
		Utility Costs (5% of Drainageway Costs)				$ 1,000	
		Contingency (30%)				$ 6,600	
		Engineering, Admin, Legal Services (20%)				$ 4,400	
		Operations & Maintenance for Pond (50-years)	AC-FT/YR	8	$ 5,000.00	$ 40,000	**$ 73,000**
Willow Creek (STA 130+00 to 153+00)	Centennial/SEMSWA	Soil Riprap Armoring	CY	500	$ 65.00	$ 32,500	
		Earthwork (Haul off site)	CY	950	$ 20.00	$ 19,000	
		Revegetation	AC	0.25	$ 2,500.00	$ 625	
		Low Flow Channel Repair	LF	1000	$ 100.00	$ 100,000	
		Mobilization Costs (5% of Drainageway Costs)				$ 7,606	
		Utility Costs (5% of Drainageway Costs)				$ 7,606	
		Contingency (30%)				$ 50,201	
		Engineering, Admin, Legal Services (20%)				$ 33,468	
		Operations & Maintenance (50-years)	LS	1	$ 107,900.00	$ 107,900	**$ 358,906**
Willow Creek (STA 153+00 to 200+00)	City of Lone Tree	Low Flow Channel Repair	LF	250	$ 100.00	$ 25,000	
		Water Quality Outlet Structure	EA	2	$ 20,000.00	$ 40,000	
		75 Acre-Foot Detention Pond	AC-FT	75	9000*AC-FT+40,000	$ 715,000	
		Earthwork (Haul off site)	CY	41000	$ 20.00	$ 820,000	
		Soil Riprap Armoring	CY	10900	$ 65.00	$ 708,500	
		Outlet Protection	EA	1	$ 25,000.00	$ 25,000	
		Revegetation	AC	4.5	$ 2,500.00	$ 11,250	
		Mobilization Costs (5% of Drainageway Costs)				$ 117,238	
		Utility Costs (5% of Drainageway Costs)				$ 117,238	
		Contingency (30%)				$ 773,768	
		Engineering, Admin, Legal Services (20%)				$ 515,845	
		Operations & Maintenance for Pond (50-years)	AC-FT/YR	75	$ 100	$ 175,900	
		Operations & Maintenance (50-years)	LS	1	$ 218,100.00	$ 218,100	**$ 4,262,838**

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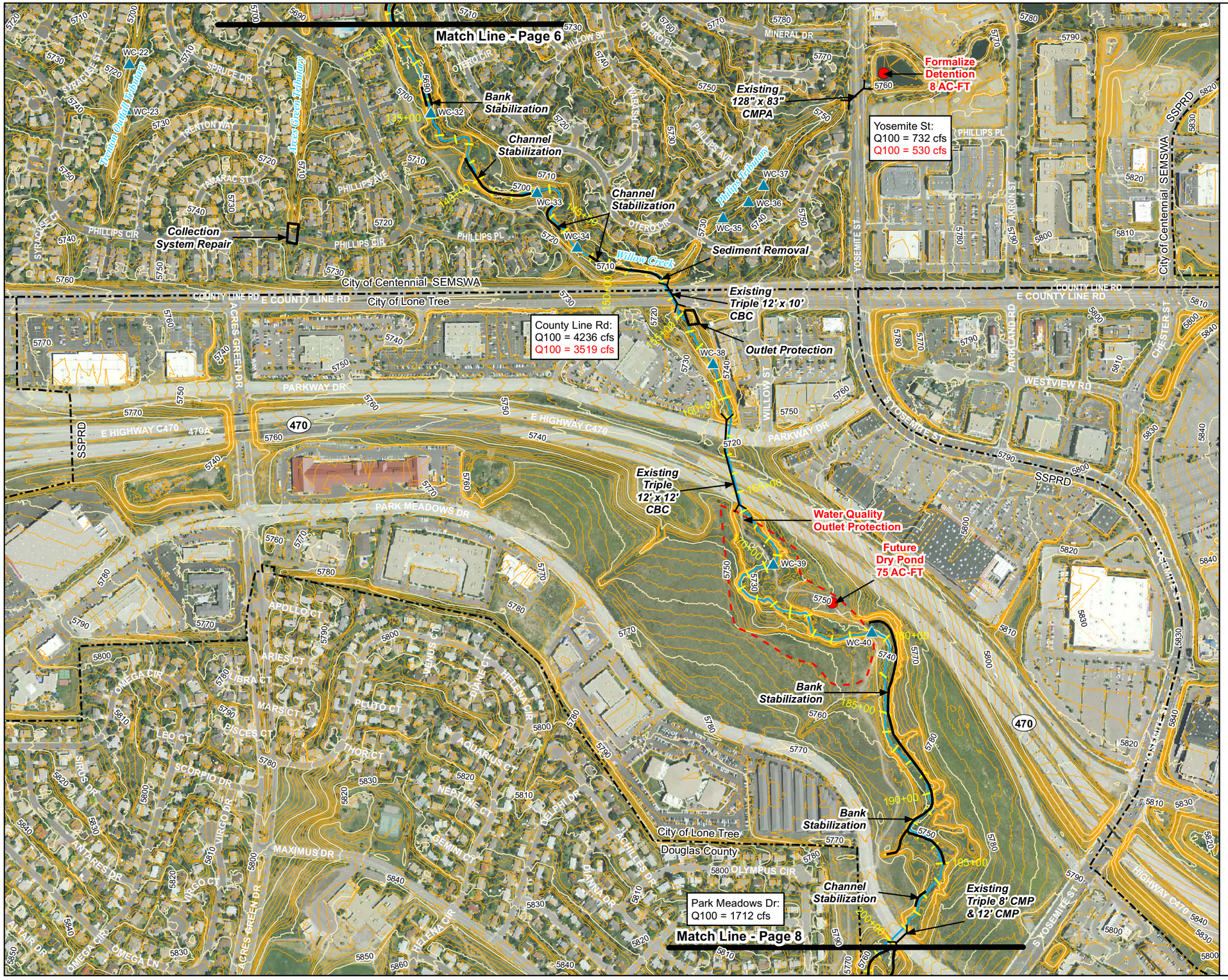

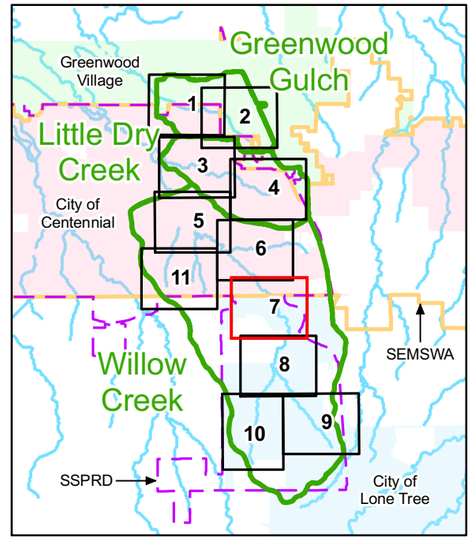

LEGEND

- Jurisdictional Boundary
- Watershed Boundary
- Existing Detention

Existing Drop Structures

- Greenwood Gulch
- Little Dry Creek
- Willow Creek

Alternatives

- Repair Alternative
- Recommended Alternative
- New Drop Structure

N W E S

Recommended Alternative
Willow Creek
Acres Green Tributary
Trenton Outfall Tributary
Phillips Tributary

Page 7

0 250 500
Feet

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Recommended Alternative Commentary Page 8

Willow Creek - Park Meadows Drive to Upstream of Yosemite Street (Station 200+00 to Station 268+00)

Cook Creek - Station 0+00 to Station 25+00

Reach Description - Cook Creek is an approximately 1.6 mile long tributary to Willow Creek located entirely in the City of Lone Tree. The upper reaches of Cook Creek are bordered by single family residential development. In the past, the channel was been improved with grouted boulder drop structures and turf grass overbanks. Much of the channel travels through Lone Tree Golf Course, where the channel is characterized by dense willows along the water edge and a series of drop structures to control the grade. The channel flows into a large storm water detention pond that has a large permanent pool and is a feature on the golf course. The outfall of the pond passes under Lone Tree Parkway and discharges adjacent to the Lone Tree Civic Center. Cook Creek continues to the north through an open space area and confluences with the main stem of Willow Creek at Cook Creek Park located North of Lone Tree Parkway and West of Yosemite St. The Main Stem of Willow Creek has a bike trail that parallels the channel from this reach to the downstream limits of the study at Englewood Dam. The channel through this reach is deep and narrow with locations of low flow channel degradation and bank erosion. Vegetation in this reach is mature with various tree species, willows, and native grasses. The channel continues to the north and crosses both Maximus Drive and Park Meadows Drive. As the channel leaves the open space and enters a more urbanized setting the vegetation along the channel is characterized by more grasses and fewer willows and trees.

Cook Creek Combination Alternative Improvements - Stabilize the channel banks between stations 25+00 to 30+00. Complete costs for this repair are included on Sheet 10. Only O&M costs are accounted for on this sheet.

Willow Creek Combination Alternative Improvements - Upstream of the confluence of Cook and Willow Creek (268+00 to 237+00) repair the channel between stations 247+30 and 249+30. Install a water quality outlet structure at the existing Willow Creek Regional Pond outlet. Stabilize the bank between stations 263+10 and 264+90 and between stations 266+20 and 267+50. Stabilize the low flow channel between stations 203+00 and 206+55, 209+20 and 210+60, and between stations 228+50 and 230+30. Below the confluence of Cook and Willow Creek stabilize the bank between stations 212+50 and 216+00, including the tributary coming in from the southwest at station 215+00. Stabilize the banks between stations 218+00 and 220+00, and between stations 220+90 and 222+30. Stabilize the low flow channel between stations 200+00 and 203+00, including the Heritage Hills Tributary. Stabilize the bank between stations 223+00 and 224+45, and between stations 230+50 and 232+30. Stabilize the low flow channel between stations 234+00 and 238+40. Install grade control drop structures at the headcuts on the tributary located in Sweetwater Park.

Drainageway	Jurisdiction	Item	Unit	Quantity	Unit Cost	Total Cost	Reach Cost
Cook Creek (STA 0+00 to 26+00)	City of Lone Tree	Operations and maintenance (50 years)	LS	1	$ 122,000.00	$ 122,000	**$ 122,000**
Willow Creek (STA 203+00 to 232+00)	Douglas County	Low Flow Channel Repair	LF	1650	$ 100.00	$ 165,000	
		Earthwork (Haul off site)	CY	13500	$ 20.00	$ 270,000	
		Soil Riprap Armoring	CY	4500	$ 65.00	$ 292,500	
		Grouted Boulder Drops	EA	2	$ 75,000	$ 150,000	
		Revegetation	AC	2	$ 2,500.00	$ 5,000	
		Mobilization Costs (5% of Drainageway Costs)				$ 44,125	
		Utility Costs (5% of Drainageway Costs)				$ 44,125	
		Contingency (30%)				$ 291,225	
		Engineering, Admin, Legal Services (20%)				$ 194,150	
		Operations & Maintenance (50-years)	LS	1	$ 122,000.00	$ 122,000	**$ 1,578,125**
Willow Creek (STA 232+00 to 268+00)	City of Lone Tree	Low Flow Channel Repair	LF	600	$ 100.00	$ 60,000	
		Earthwork (Haul off site)	CY	2970	$ 20.00	$ 59,400	
		Soil Riprap Armoring	CY	1155	$ 65.00	$ 75,075	
		Revegetation	AC	0.5	$ 2,500.00	$ 1,250	
		Water Quality Outlet Structure	EA	1	$ 20,000.00	$ 20,000	
		Mobilization Costs (5% of Drainageway Costs)				$ 10,786	
		Utility Costs (5% of Drainageway Costs)				$ 10,786	
		Contingency (30%)				$ 71,189	
		Engineering, Admin, Legal Services (20%)				$ 47,460	
		Operations & Maintenance (50-years)	LS	1	$ 319,000.00	$ 319,000	**$ 674,946**

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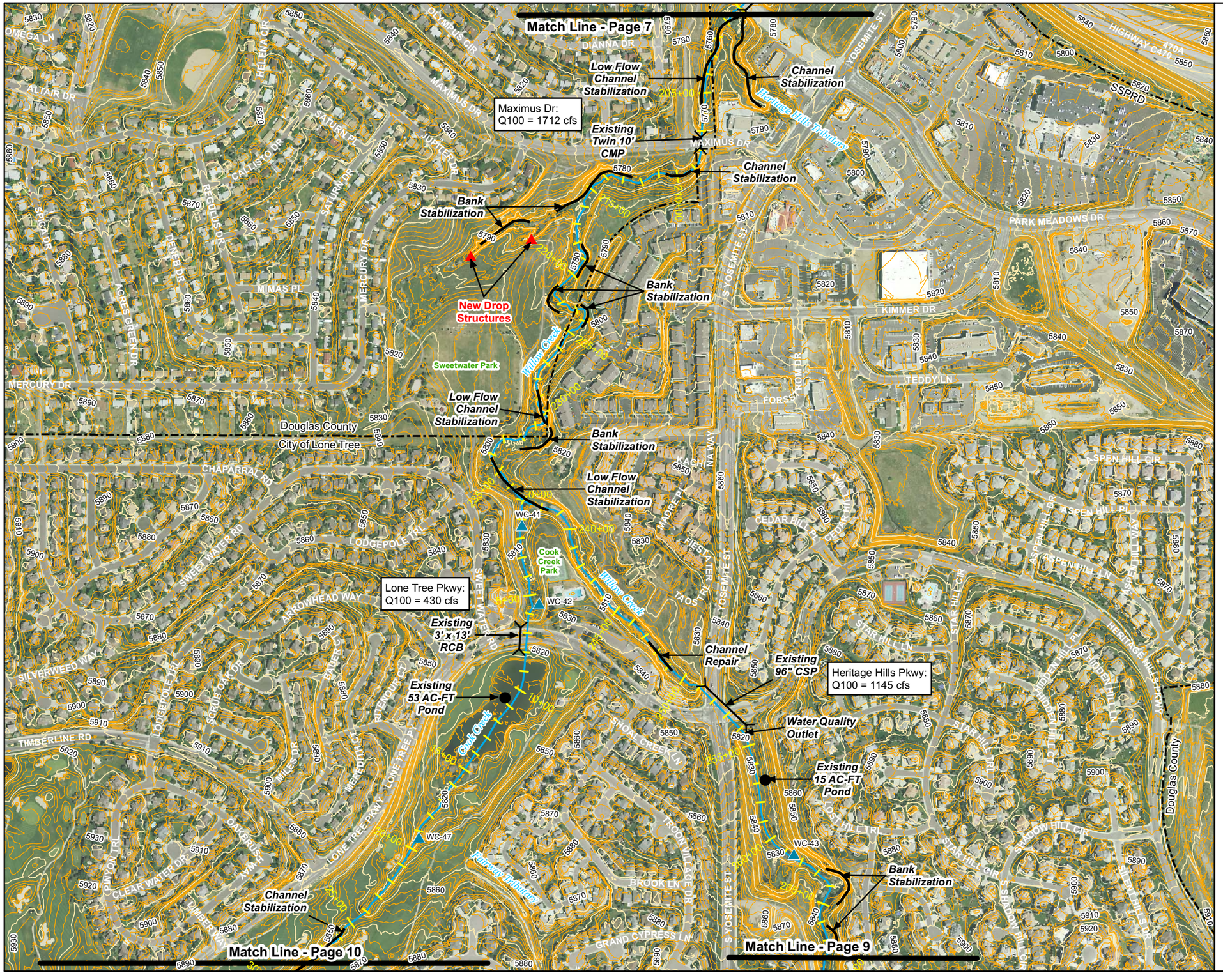

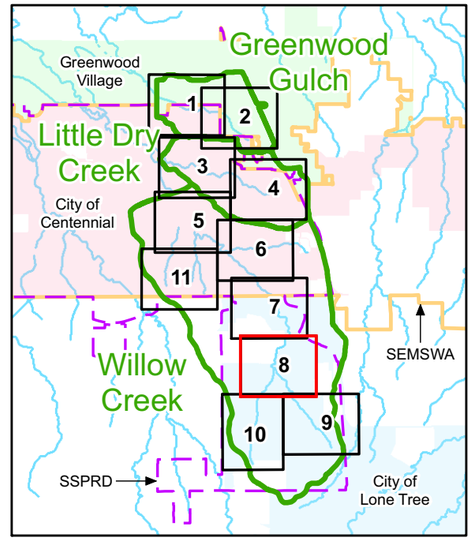

LEGEND

- Jurisdictional Boundary
- Watershed Boundary
- Existing Detention

Existing Drop Structures

- Greenwood Gulch
- Little Dry Creek
- Willow Creek

Alternatives

- Repair Alternative
- Recommended Alternative
- New Drop Structure

N W E S

Recommended Alternative
Willow Creek
Heritage Hills Tributary
Fairway Tributary
Cook Creek
Page 8

0 250 500
Feet

CH2MHILL

Recommended Alternative Commentary Page 9

Willow Creek - Upstream of Yosemite Street to Park Meadows Blvd. (Station 268+00 to Station 317+11)

Reach Description - Sheet nine depicts the upper portion of the watershed where Willow Creek begins. It is the southern project limits upstream of Lincoln Ave. and is roughly is adjacent to the Sky Ridge Hospital. Being in the upper parts of the watershed there is not a well defined channel in this reach except for a few constructed channels that are a result of local development and are located adjacent to the mainstem. An existing stock pond collects flows from Willow Creek, just south of Lincoln Ave and pipes the flow under the road to the north. The small un-named tributary to the west of the Lincoln crossing discharges to a stormwater detention pond that also discharges to the main stem of Willow Creek north of Lincoln. The reach located between Lincoln Ave and Heritage Hills Parkway has been improved and is characterized by a riprap lined low flow channel and grass lined channel banks. Downstream of the Heritage Hills Parkway crossing the channel has been encroached upon by residential development as well as an elementary school. The channel is lined with mature vegetation but there are multiple locations where bank erosion, most frequently at the outside bends, occurs.

Willow Creek Combination Alternative Improvements - Stabilize the outfall at station 271+00 and stabilize the banks between stations 273+00 and 275+50 and also between stations 285+00 and 289+40. Along with the stabilization there is failing drop structure that needs to be replaced at station 294+15.

Drainageway	Jurisdiction	Item	Unit	Quantity	Unit Cost	Total Cost	Reach Cost
Willow Creek (STA 268+00 to 317+11)	City of Lone Tree	Grouted Boulder Drop Structure	EA	1	$ 75,000	$ 75,000	
		Outfall Stabilization	EA	1	$ 25,000	$ 25,000	
		Earthwork (Haul off site)	CY	5940	$ 20	$ 118,800	
		Soil Riprap Armoring	CY	2100	$ 65	$ 136,500	
		Revegetation	AC	1	$ 2,500	$ 2,500	
		Mobilization Costs (5% of Drainageway Costs)				$ 17,890	
		Utility Costs (5% of Drainageway Costs)				$ 17,890	
		Contingency (30%)				$ 118,074	
		Engineering, Admin, Legal Services (20%)				$ 78,716	
		Operations & Maintenance for Pond (50-years)	AC-FT/YR	25	$ 100	$ 58,600	
		Operations & Maintenance (50-years)	LS	1	$ 230,400	$ 230,400	**$ 879,370**

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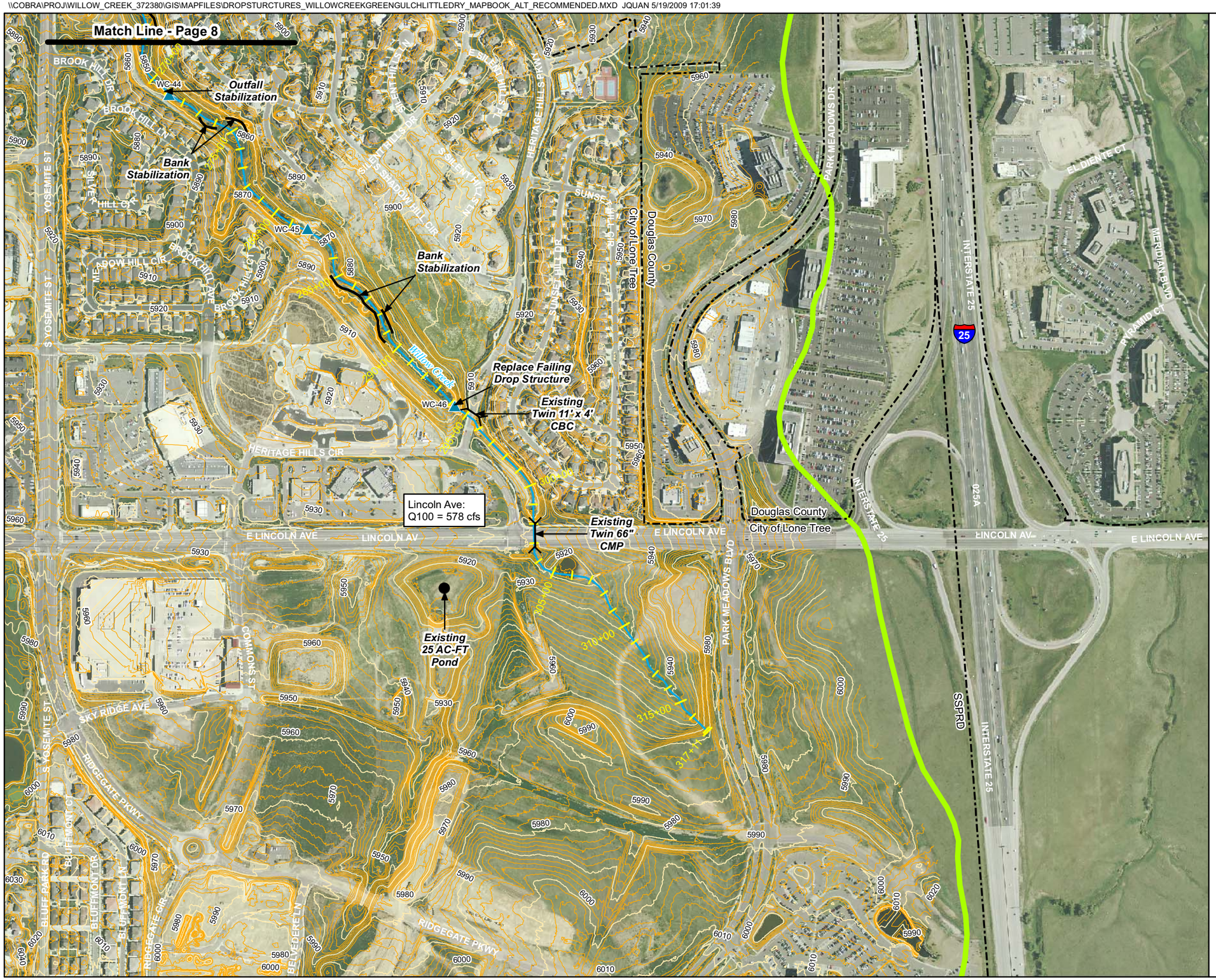

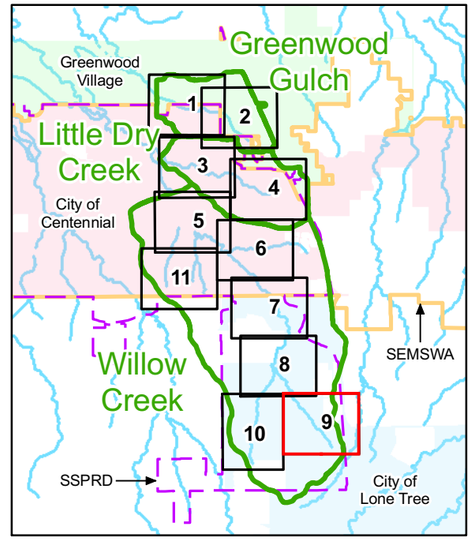

LEGEND

- Jurisdictional Boundary
- Watershed Boundary
- Existing Detention

Existing Drop Structures

- Greenwood Gulch
- Little Dry Creek
- Willow Creek

Alternatives

- Repair Alternative
- Recommended Alternative
- New Drop Structure

N W E S

Recommended Alternative
Willow Creek

0 250 500
Feet

Page 9

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APPENDIX E

Wetland/Riparian Inventory

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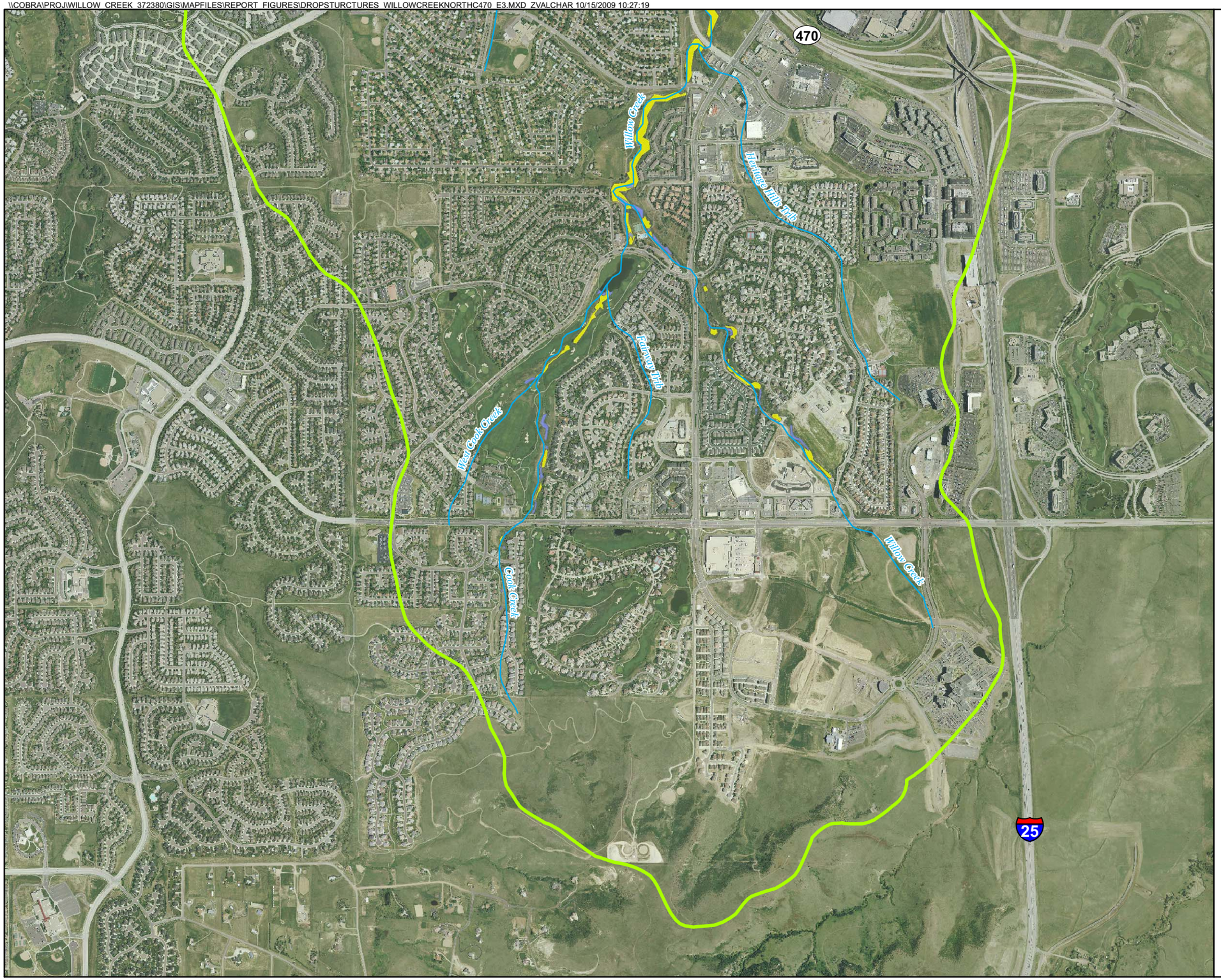
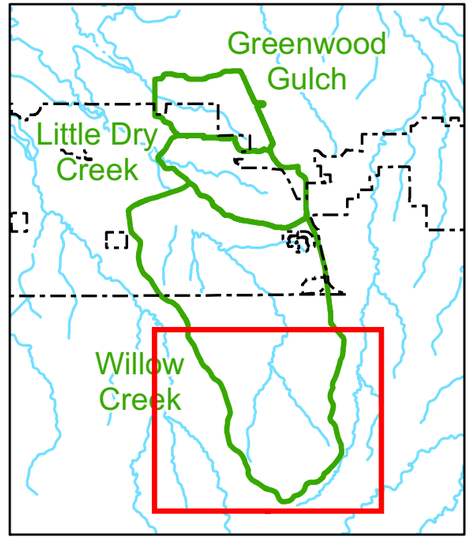




Legend

- Streams
- Drainage Basins
- City of Centennial
- Managed Wetland
- Emergent Wetland
- Seasonal Wetland
- Managed Channel
- Reclaimed Channel
- Riparian Scrub Shrub

N
W E
S

0 750 1,500
Feet

Willow Creek
South of C-470
Wetland and Riparian Zones
Figure E4

CH2MHILL

APPENDIX F

Plan and Profile Drawings

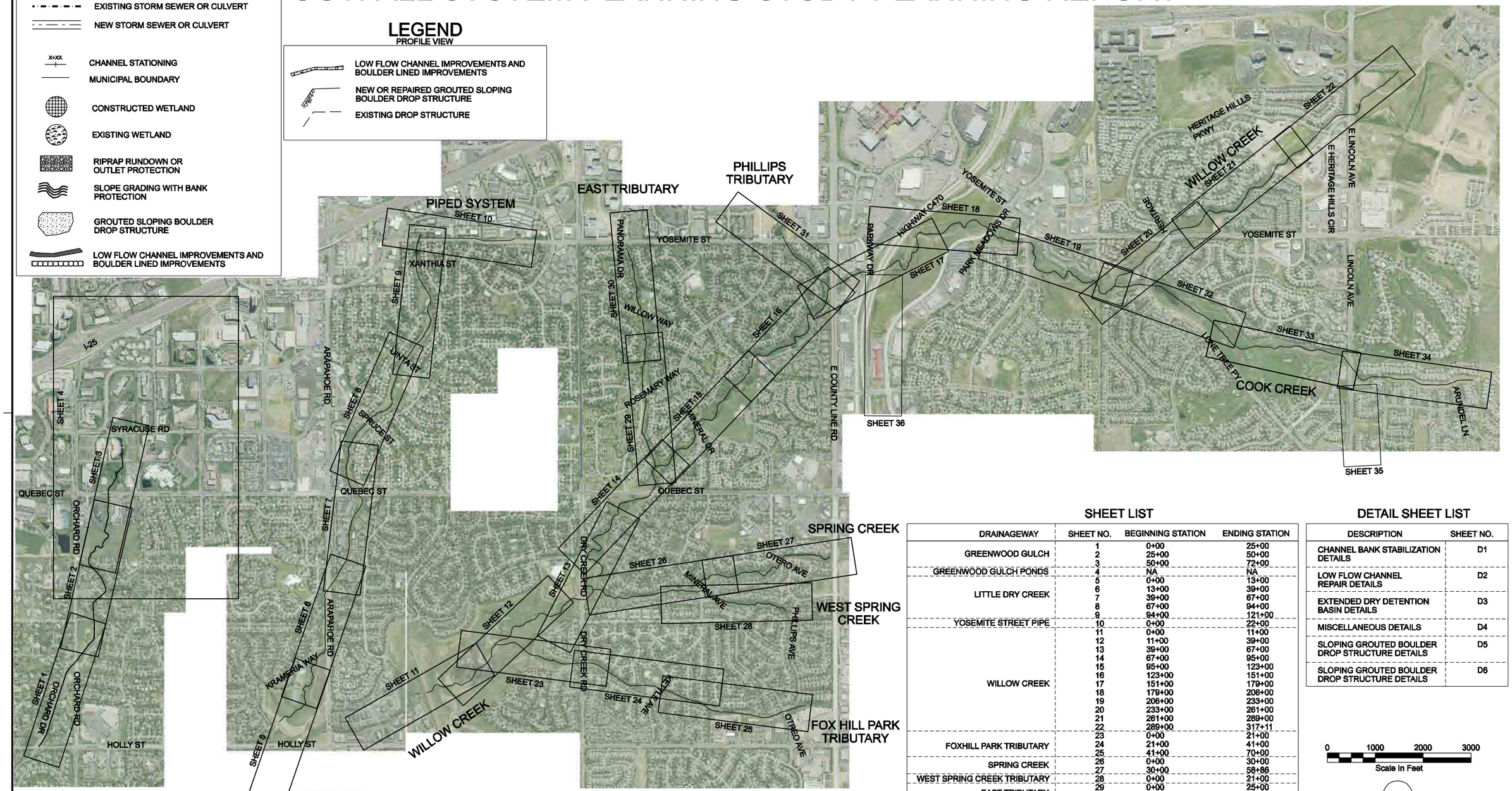
WILLOW CREEK, LITTLE DRY CREEK AND GREENWOOD GULCH OUTFALL SYSTEM PLANNING STUDY PLANNING REPORT

LEGEND
PLAN VIEW

- EXISTING CONTOUR
- EXISTING STORM SEWER OR CULVERT
- NEW STORM SEWER OR CULVERT
- X+XX CHANNEL STATIONING
- MUNICIPAL BOUNDARY
- CONSTRUCTED WETLAND
- EXISTING WETLAND
- RIPRAP RUNDOWN OR OUTLET PROTECTION
- SLOPE GRADING WITH BANK PROTECTION
- GROUTED SLOPING BOULDER DROP STRUCTURE
- LOW FLOW CHANNEL IMPROVEMENTS AND BOULDER LINED IMPROVEMENTS

LEGEND
PROFILE VIEW

- LOW FLOW CHANNEL IMPROVEMENTS AND BOULDER LINED IMPROVEMENTS
- NEW OR REPAIRED GROUTED SLOPING BOULDER DROP STRUCTURE
- EXISTING DROP STRUCTURE



SHEET LIST

DRAINAGEWAY	SHEET NO.	BEGINNING STATION	ENDING STATION
GREENWOOD GULCH	1	0+00	25+00
	2	25+00	50+00
	3	50+00	72+00
GREENWOOD GULCH PONDS	4	NA	NA
LITTLE DRY CREEK	5	0+00	13+00
	6	13+00	39+00
	7	39+00	67+00
	8	67+00	94+00
	9	94+00	121+00
YOSEMITE STREET PIPE	10	0+00	22+00
WILLOW CREEK	11	0+00	11+00
	12	11+00	39+00
	13	39+00	67+00
	14	67+00	95+00
	15	95+00	123+00
	16	123+00	151+00
	17	151+00	179+00
	18	179+00	206+00
	19	206+00	233+00
	20	233+00	261+00
	21	261+00	289+00
	22	289+00	317+11
FOXHILL PARK TRIBUTARY	23	0+00	21+00
	24	21+00	41+00
	25	41+00	70+00
SPRING CREEK	26	0+00	30+00
	27	30+00	58+86
WEST SPRING CREEK TRIBUTARY	28	0+00	21+00
EAST TRIBUTARY	29	0+00	25+00
	30	25+00	47+74
PHILLIPS TRIBUTARY	31	0+00	15+55
COOK CREEK	32	84+10	57+00
	33	57+00	29+00
	34	29+00	0+00
LONE TREE PONDS	35	NA	NA
	36	NA	NA

DETAIL SHEET LIST

DESCRIPTION	SHEET NO.
CHANNEL BANK STABILIZATION DETAILS	D1
LOW FLOW CHANNEL REPAIR DETAILS	D2
EXTENDED DRY DETENTION BASIN DETAILS	D3
MISCELLANEOUS DETAILS	D4
SLOPING GROUTED BOULDER DROP STRUCTURE DETAILS	D5
SLOPING GROUTED BOULDER DROP STRUCTURE DETAILS	D6

0 1000 2000 3000
Scale In Feet

N

MAPPING PRODUCED BY: SANBORN/USGS (7/2008)
HORIZONTAL DATUM: NAD 83 FEET
STATE PLANE COLORADO CENTRAL
VERTICAL DATUM: NAVD 88

CH2MHILL
9193 SOUTH JAMAICA STREET
ENGLEWOOD, CO 80112

		DATE
DESIGNED	CH	1.1/13/09
DRAWN	MM	1.1/13/09
CHECKED	MG	1.1/13/09
REVISED	MM	1.1/13/09

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, DOUGLAS COUNTY
CITY OF LONE TREE, SOUTHEAST METRO STORMWATER AUTHORITY,
GREENWOOD VILLAGE, SOUTH SUBURBAN PARKS AND RECREATION

WILLOW CREEK, LITTLE DRY CREEK AND GREENWOOD GULCH OUTFALL SYSTEM PLANNING STUDY PLANNING REPORT

INDEX SHEET

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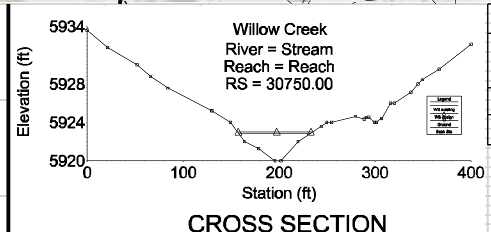
Commentary Page 22

Willow Creek - Station 289+00 to Station 317+11

Reach Description - Willow Creek, UDFCD Drainageway ID 5402, has the largest contributing area to the downstream project limit of Holly Street. In general, flow in the Willow Creek watershed is from the south to the north and has approximately 15.4 miles of stream length including tributaries The Willow Creek drainageway includes a series of tributary streams that make up the stream network for the watershed.
This sheet depicts the upper portion of the watershed where Willow Creek begins. It is the southern project limits upstream of Lincoln Avenue and is roughly adjacent to the Sky Ridge Hospital. An existing stock pond collects flows from Willow Creek, just south of Lincoln Ave and pipes the flow under the road to the north. The reach located between Lincoln Ave and Heritage Hills Parkway has been improved and is characterized by a riprap lined low flow channel and grass lined channel banks. Downstream of the Heritage Hills Parkway crossing the channel has been encroached upon by residential development as well as an elementary school. The channel is lined with mature vegetation but there are multiple locations where bank erosion, most frequently at the outside bends, occurs.

Proposed Improvements - Stabilize the channel from station 289+00 to 290+00. The existing drop structure below the Heritage Hills Parkway crossing is to be removed and replaced.
The existing pond located south of Lincoln is to be formalized and a new water quality outlet structure constructed.

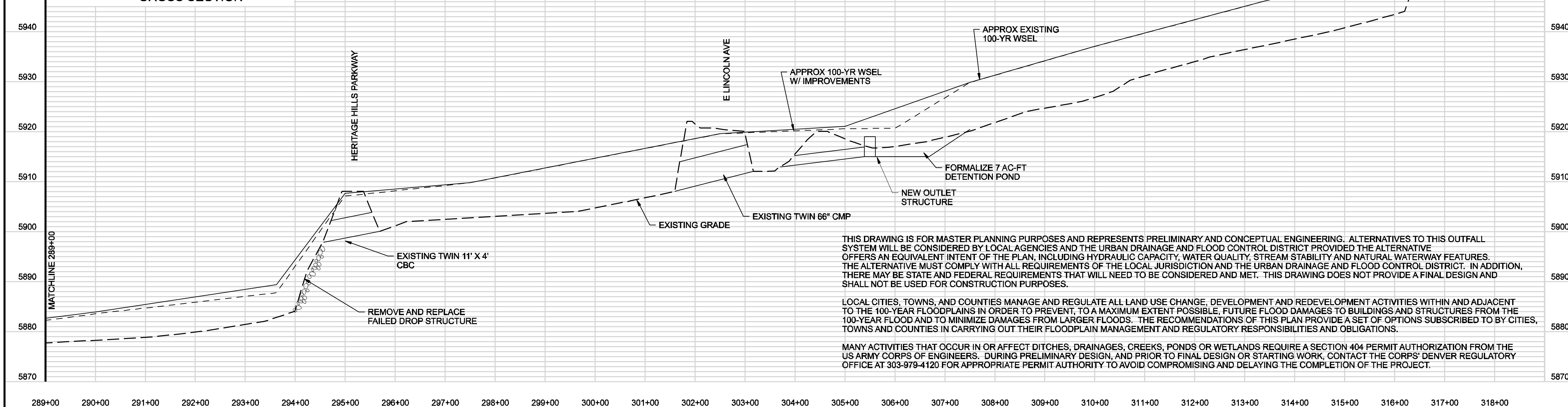
Drainageway	Jurisdiction	Item	Unit	Unit Cost	Quantity	Utility Relocation Cost	Drainageway Improvement Cost	Street Crossing Cost	Property Acquisition Cost	Total Cost
Willow Creek (STA 289+00 to 317+11)	City of Lone Tree	Grouted Boulder Drop Structure	SY	$ 300	1500	$ -	$ 450,000	$ -	$ -	$ 450,000
		New Outlet Structure	EA	$ 20,000	1	$ -	$ 20,000	$ -	$ -	$ 20,000
		Earthwork (Haul off site)	CY	$ 20	3340	$ -	$ 66,800	$ -	$ -	$ 66,800
		Soil Riprap Armoring	CY	$ 65	860	$ -	$ 55,900	$ -	$ -	$ 55,900
		Revegetation	AC	$ 5,000	0.3	$ -	$ 1,500	$ -	$ -	$ 1,500
		Utility Costs (5%)	LS	5%	1	$ 29,700	$ -	$ -	$ -	$ 29,700
		Mobilization (5%)	LS	5%	1	$ 1,500	$ 29,700	$ -	$ -	$ 31,200
		Contingency (30%)	LS	30%	1	$ 9,400	$ 187,200	$ -	$ -	$ 196,600
		Engineering, Admin, Legal Services (20%)	LS	20%	1	$ 8,100	$ 162,200	$ -	$ -	$ 170,300
		Operations & Maintenance (50-years)	LF	$ 47	2800	$ -	$ 131,600	$ -	$ -	$ 131,600
		Reach Cost				$ 48,700	$ 1,104,900	$ -	$ -	**$ 1,153,600**
		Total Sheet Cost								**$ 1,153,600**



CROSS SECTION

FLOW TABLE

FROM STA	TO STA	100-YEAR (CFS)	100-YEAR WITH IMPROVEMENTS (CFS)
285+00	303+00	715	390
303+00	317+11	608	608



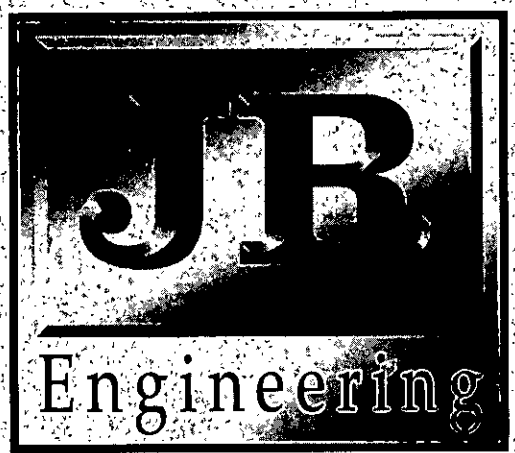
THIS DRAWING IS FOR MASTER PLANNING PURPOSES AND REPRESENTS PRELIMINARY AND CONCEPTUAL ENGINEERING. ALTERNATIVES TO THIS OUTFALL SYSTEM WILL BE CONSIDERED BY LOCAL AGENCIES AND THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT PROVIDED THE ALTERNATIVE OFFERS AN EQUIVALENT INTENT OF THE PLAN, INCLUDING HYDRAULIC CAPACITY, WATER QUALITY, STREAM STABILITY AND NATURAL WATERWAY FEATURES. THE ALTERNATIVE MUST COMPLY WITH ALL REQUIREMENTS OF THE LOCAL JURISDICTION AND THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT. IN ADDITION, THERE MAY BE STATE AND FEDERAL REQUIREMENTS THAT WILL NEED TO BE CONSIDERED AND MET. THIS DRAWING DOES NOT PROVIDE A FINAL DESIGN AND SHALL NOT BE USED FOR CONSTRUCTION PURPOSES.

LOCAL CITIES, TOWNS, AND COUNTIES MANAGE AND REGULATE ALL LAND USE CHANGE, DEVELOPMENT AND REDEVELOPMENT ACTIVITIES WITHIN AND ADJACENT TO THE 100-YEAR FLOODPLAINS IN ORDER TO PREVENT, TO A MAXIMUM EXTENT POSSIBLE, FUTURE FLOOD DAMAGES TO BUILDINGS AND STRUCTURES FROM THE 100-YEAR FLOOD AND TO MINIMIZE DAMAGES FROM LARGER FLOODS. THE RECOMMENDATIONS OF THIS PLAN PROVIDE A SET OF OPTIONS SUBSCRIBED TO BY CITIES, TOWNS AND COUNTIES IN CARRYING OUT THEIR FLOODPLAIN MANAGEMENT AND REGULATORY RESPONSIBILITIES AND OBLIGATIONS.

MANY ACTIVITIES THAT OCCUR IN OR AFFECT DITCHES, DRAINAGES, CREEKS, PONDS OR WETLANDS REQUIRE A SECTION 404 PERMIT AUTHORIZATION FROM THE US ARMY CORPS OF ENGINEERS. DURING PRELIMINARY DESIGN, AND PRIOR TO FINAL DESIGN OR STARTING WORK, CONTACT THE CORPS' DENVER REGULATORY OFFICE AT 303-979-4120 FOR APPROPRIATE PERMIT AUTHORITY TO AVOID COMPROMISING AND DELAYING THE COMPLETION OF THE PROJECT.

DV99-178

PHASE III DRAINAGE REPORT
HERITAGE HILLS
FILING NO. 1-F



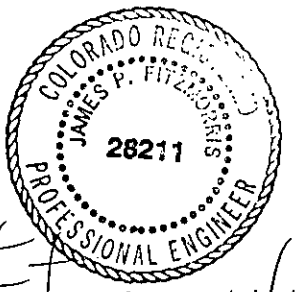
PHASE III DRAINAGE REPORT
HERITAGE HILLS
FILING NO. 1-F

Prepared for:

Celebrity Development Corporation
304 Inverness Way South, Suite 180
Englewood, CO 80112-5820

Prepared by:

JR ENGINEERING, LTD.
6110 Greenwood Plaza Boulevard
Englewood, Colorado 80111
(303) 740-9393



11/17/99

July, 1999
Job Number 3216.06
X:\321606\Wp\Reports\321606-D3.doc

CERTIFICATIONS

This report (plan) for the Phase III drainage design of Heritage Hills Filing No. 1-F was prepared by me (or under my direct supervision) in accordance with the provisions of Douglas County Drainage Design and Technical Criteria for the owners thereof. I understand that Douglas County does not and will not assume liability for drainage facilities designed by others.

11/17/99

James P. Fitzmorris, P.E.
Colorado No. 28211
For and on behalf of JR Engineering

COLORADO JAMES P. FITZMORRIS 28211 PROFESSIONAL ENGINEER

Celebrity Development hereby certifies that the drainage facilities for Heritage Hills Filing No. 1-F shall be constructed according to the design presented in this report. I understand that Douglas County does not and will not assume liability for the drainage facilities designed and/or certified by my engineer and that Douglas County reviews drainage plans pursuant to Colorado Revised Statutes, Title 30, Article 28; but cannot, on behalf of Heritage Hills Filing No. 1-F, guarantee the final drainage design review will absolve Celebrity Development Corporation and/or their successors and/or assigns of future liability for improper design. I further understand that approval of the Final Plat does not imply approval of my engineer's drainage design.

Celebrity Development Corp.
Name of Developer

Authorized Signature

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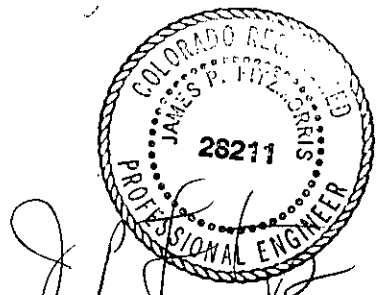


11/17/99

INTRODUCTION

This report represents a Phase III Drainage Report for a site consisting of five commercial lots at Heritage Hills Filing No. 1–F and was prepared to comply with regulatory requirements of Douglas County, Colorado. The report was prepared following guidelines and regulations with the Douglas County Storm Drainage Design and Technical Criteria (Reference 1) and the Urban Storm Drainage Criteria Manual (Reference 2).

This report addresses post-development flood peaks within the site at Heritage Hills Filing No. 1-F for the 5-year minor storm event and the 100-year major storm event. Final design calculations are provided herein.

GENERAL LOCATION AND DESCRIPTION

Location

The proposed commercial lots at Heritage Hills Filing No. 1-F are located in Section 10, Township 6 South, Range 67 West of the Sixth Principal Meridian in Douglas County (see Vicinity Map in Appendix). The project site is bordered on the west by Safeway Marketplace, on the north by a proposed school and park site, on the east by Willow Creek and future Heritage Hills filings and on the south by Lincoln Avenue.

The Heritage Hills Filing No. 1-F site consists of five commercial lots and open space on 8.29 acres of undeveloped ground. The site will be overlotted prior to construction as a part of the overall Heritage Hills development. The site has historically been used for agricultural uses; existing onsite vegetation consists of native grasses. The Soil Conservation Service "Soil Survey of Castle Rock Area, Colorado" (Reference 3) indicates soils are Hydrologic Soil Group C (Fondis clay loam and Renohill-Buick complex) which have moderately high runoff potential.

DRAINAGE BASINS AND SUB-BASINS

Major Basin Description

The site at Heritage Hills Filing No. 1-F lies within the Willow Creek Watershed, a tributary of Little Dry Creek, and is conveyed to the South Platte River through downtown Englewood. The tributary area upstream of Heritage Hills is primarily undeveloped, with some areas being used for pastureland. The basin is covered with natural grasses and vegetation with no significant tree cover. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (Reference 4) does not indicate any designated 100-year floodplains on or immediately adjacent to the site. The areas covered by the site were previously addressed in the Phase III Drainage Study for Heritage Hills Filing No. 1 prepared by JR Engineering, Ltd. in April 1995 (Reference 5) and revised in December 1995 (Reference 6) and the Willow Creek Improvements at Heritage Hills Flood plain Study, June 1998, by JR Engineering.

Offsite Basins

Emergency overflow drainage from an adjacent property crosses Lincoln Avenue onto the west end of the site through a 50' drainage ditch. This was identified in the Phase III study for Heritage Hills Filing No. 1 delineated as Basin 2 draining approximately 200 acres and the Willow Creek improvements at Heritage Hills Floodplain Study, June 1998, by JR Engineering Ltd.

DRAINAGE DESIGN CRITERIA

Regulations

Storm drainage analysis and design criteria used for this project were taken from the "Douglas County Storm Drainage Design and Technical Criteria" (DCSDDTC) and the "Urban Storm Drainage Criteria Manual" (USDCM) as required by Douglas County.

The drive aisles and lanes within the project will be private and maintained by the owners. The proposed roadways adjacent to the site on the north and northeast will be

dedicated to the public and maintained by the County. The allowable surface flows for both the interior drive aisles and dedicated roadways were calculated using the criteria given in the Douglas County manual. Detention for the site is provided in a downstream facility approved in the Phase III study for Heritage Hills.

Development Criteria

The Heritage Hills site lies within Rainfall Zone I as shown on Figure 501 in the Douglas County Storm Drainage Design and Technical Criteria manual. Rainfall data for this zone was used for all calculations in this report.

The 5-year storm was used as the minor storm event and was used for sizing of onsite storm sewer inlets and collection pipes with the exception of the sump inlets located on Heritage Hills Parkway. The 100-year storm was used as the major storm and was used for sizing of these sump inlets.

The Rational Method was used for sizing the storm sewer system on and off site.

DRAINAGE FACILITY DESIGN

General Concept

Runoff from the proposed development is conveyed overland to valley pans and curb and gutter. The valley pans and curb and gutter convey the runoff to storm sewers through two inlets along Heritage Hills Circle. The two inlets have been designed to capture the entire flow from sub-areas A, B, C, E and F resulting from a 5-year storm and to allow a limited amount of flow form these areas to continue over to Heritage Hills Parkway during a 100-year storm. All drainage from sub-areas D and D1 will continue over to Heritage Hills Parkway. All drainage from this development is collected at the low point of Heritage Hills Parkway via sump inlets and storm pipe then outfalls through the wing wall of the Willow Creek tributary box culvert.

The entire site drains to the northeast toward Willow Creek, which discharges into an existing regional detention facility northwest of the site.

Design Details

Stormwater runoff from the site is conveyed by curb and gutter sections within allowable Limits of the drainage criteria manual. Erosion control facilities consisting of hay bales or silt fence will be placed during the construction period in accordance with the erosion control plan.

Hydrologic and hydraulic calculations are included in the Appendix.

CONCLUSIONS

This Phase III Drainage Study for the commercial lots at Heritage Hills Filing No. 1-F complies with the Douglas County Storm Drainage Design and Technical Criteria and the Urban Drainage Flood Control District Storm Drainage Criteria.

REFERENCES

1. Douglas County Storm Drainage Design And Technical Criteria, Douglas County, Colorado (rev 1986).

2. Urban Storm Drainage Criteria Manual, Urban Drainage And Flood Control District, (rev. 1992).

3. Soil Survey Of Castle Rock Area, Colorado, USDA, SCS, (rev November 1974).

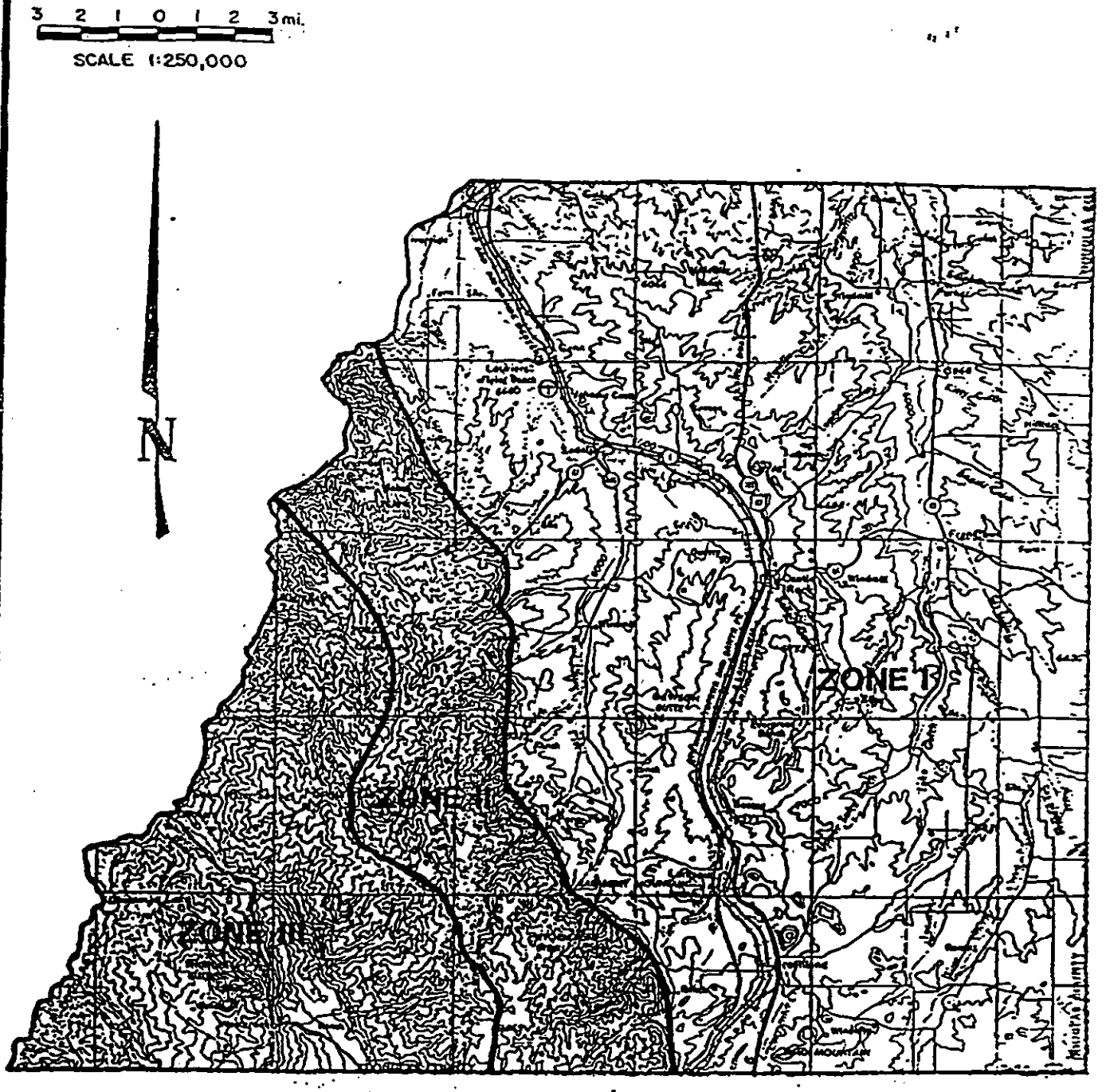
4. Federal Emergency Management Agency Flood Insurance Rate Map, Community-Panel Number 080049 0050 C, (rev September 30, 1987).

5. Phase II Drainage Study, Heritage Hills, JR Engineering, Ltd., April 24, 1995.

6. Phase III Drainage Study, Heritage Hills Filing No. 1, Jr Engineering, Ltd., Revised December 11, 1995.

7. Willow Creek Improvements at Heritage Hills, JR Engineering Ltd., June 1998.

APPENDIX A



RAINFALL ZONES

TABLE 3-1 (42)

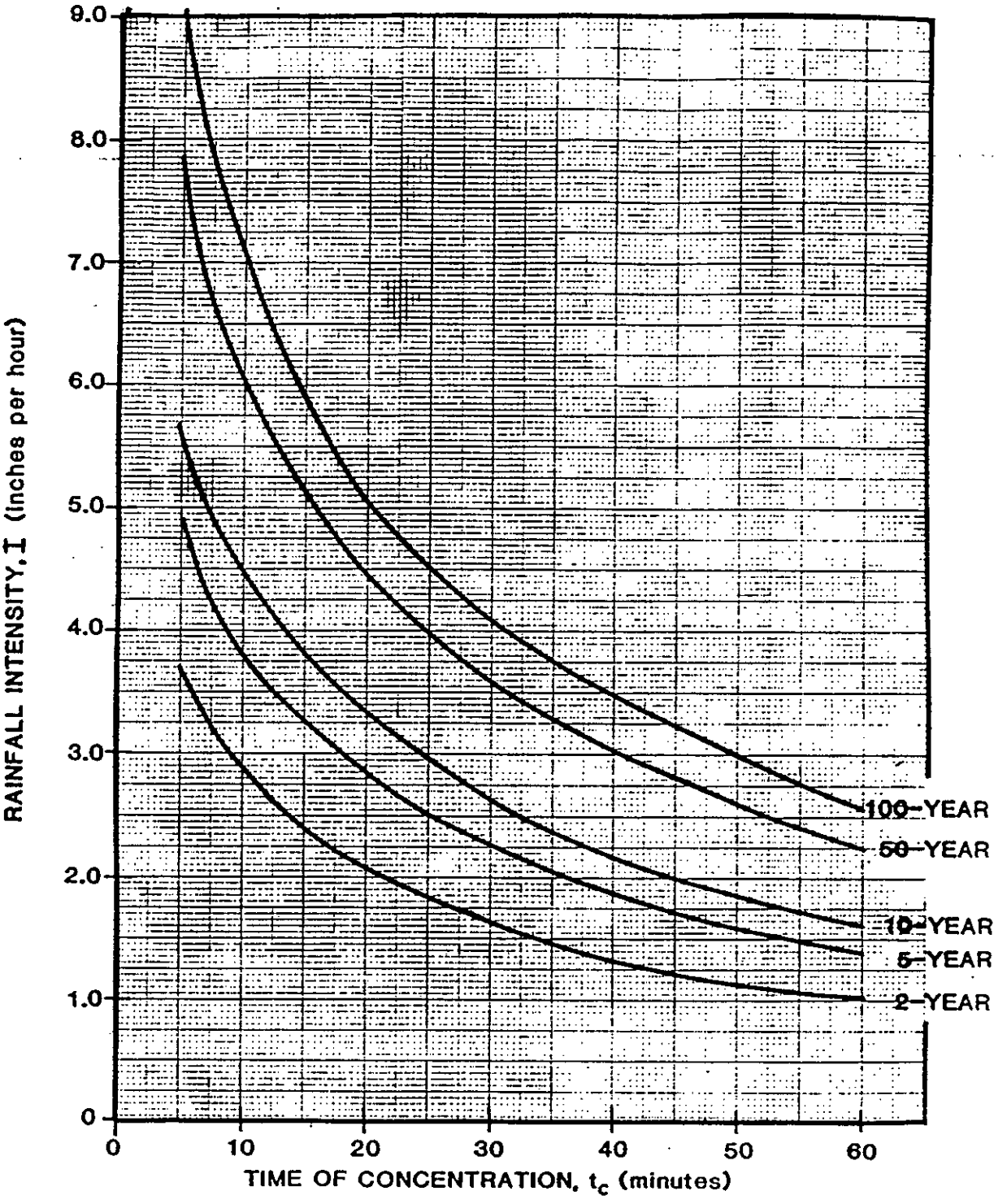
RECOMMENDED RUNOFF COEFFICIENTS AND PERCENT IMPERVIOUS

LAND USE OR SURFACE CHARACTERISTICS	PERCENT IMPERVIOUS	FREQUENCY 2	5	10	100
Business:					
Commercial Areas	95	.87	.87	.88	.89
Neighborhood Areas	70	.60	.65	.70	.80
Residential:					
Single-Family	*	.40	.45	.50	.60
Multi-Unit (detached)	50	.45	.50	.60	.70
Multi-Unit (attached)	70	.60	.65	.70	.80
1/2 Acre Lot or Larger	*	.30	.35	.40	.60
Apartments	70	.65	.70	.70	.80
Industrial:					
Light Areas	80	.71	.72	.76	.82
Heavy Acres	90	.80	.80	.85	.90
Parks, Cemetaries:	7	.10	.18	.25	.45
Playgrounds:	13	.15	.20	.30	.50
Schools:	50	.45	.50	.60	.70
Railroad Yard Areas	20	.20	.25	.35	.45
Undeveloped Areas:					
Historic Flow Analysis- Greenbelts, Agricultural	2	(See "Lawns")			
Offsite Flow Analysis (when land use not defined)	45	.43	.47	.55	.65
Streets:					
Paved	100	.87	.88	.90	.93
Gravel (Packed)	40	.40	.45	.50	.60
Drive and Walks:	96	.87	.87	.88	.89
Roofs:	90	.80	.85	.90	.90
Lawns, Sandy Soil	0	.00	.01	.05	.20
Lawns, Clayey Soil	0	.05	.15	.25	.50

NOTE: These Rational Formula coefficients may not be valid for large basins.

*See Figure 2-1 for percent impervious.

TIME - INTENSITY - FREQUENCY CURVES
ZONE I



Date: NOV 1984
Rev:

REFERENCE: WRC TM-1, 5-24-1984

STANDARD FORM SF-2
TIME OF CONCENTRATION

Subdivision HERITAGE HILLS
Location DOUGLAS COUNTY

Project Name: FILING 1-F
Project No. 3216.06
Calculated By: MK
Checked By:
Date: 7/13/99

SUB-BASIN DATA			INITIAL/OVERLAND (T_i)			TRAVEL TIME (T_t)				Tc CHECK (URBANIZED BASINS)			FINAL
BASIN ID	D.A. (AC)	C_5	L (FT)	S (%)	T_i (MIN)	L (FT)	S (%)	VEL. (FPS)	T_t (MIN)	COMP. T_c (MIN)	TOTAL LENGTH(FT)	MIN. T_c (MIN)	T_c (MIN)
A	2.12	0.87	250	1.60	5.6	660	1.00	2.0	5.5	11.1	910.0	15.1	11.1
B	3.33	0.87	250	3.00	4.5	460	3.00	3.5	2.2	6.7	710.0	13.9	6.7
C	2.14	0.87	250	3.0	4.5	380	3.0	3.2	2.0	6.5	630.0	13.5	6.5
D	1.11	0.88	0	0.0	0.0	1080	1.0	2.0	9.0	9.0	1080.0	16.0	9.0
E	1.80	0.87	180	3.00	4.5	220	1.00	2.0	1.8	6.3	400.0	12.2	6.3
F	1.36	0.88	0	0.00	0.0	1285	1.00	2.0	10.7	10.7	1285.0	17.1	10.7
D1	0.64	0.88	0	0.00	0.0	610	1.00	2.0	5.1	5.1	610.0	13.4	5.1

NOTES:

$T_i = (1.8*(1.1 - C_5)*(L)^{0.5})/(S^{0.33})$

T_t=L/60V (Velocity From Fig. 3-2)

Tc Check = 10+L/180

STANDARD FORM SF-3
STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)

Subdivision HERITAGE HILLS
Location DOUGLAS COUNTY
Design Storm 5-Year

Project Name: FILING 1-F
Project No. 3216.06
Calculated By: MK
Checked By:
Date: 7/13/99

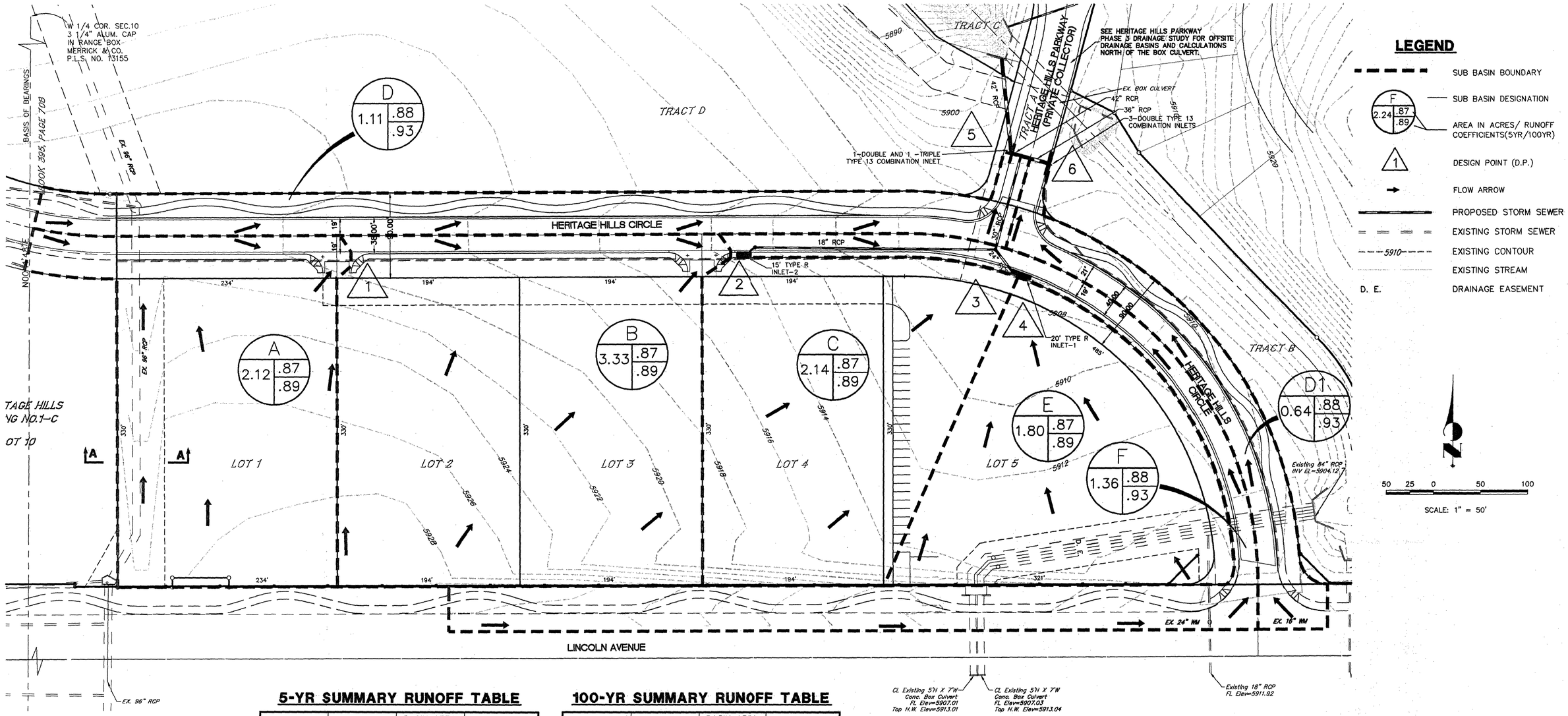
STREET	Design Point	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			
		Area Desig.	Area (Ac)	Runoff Coeff.	Tc (min)	C*A (Ac)	I (in/hr)	Q (cfs)	Tc (min)	C*A (Ac)	I (in/hr)	Q (cfs)	Slope (%)	Street Flow (cfs)	Design Flow (cfs)	Slope (%)	Pipe Size (inches)	Length (ft)	Velocity (fps)	Tt (min)	
	1	A	2.12	0.87	11.1	1.84	2.75	5.10													
	2	B	3.33	0.87	6.7	2.90	3.30	9.60													
	3	C	2.14	0.87	6.5	1.86	3.35	6.24													
	5	D	1.11	0.88	9.0	0.98	2.90	2.84													
	4	E	1.80	0.87	6.3	1.57	3.40	5.30													
	4	F	1.36	0.88	10.7	1.20	2.75	3.30													
	6	D1	0.64	0.88	5.1	0.56	4.90	2.70													

STANDARD FORM SF-3
STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)

Subdivision HERITAGE HILLS
Location DOUGLAS COUNTY
Design Storm 100-Year

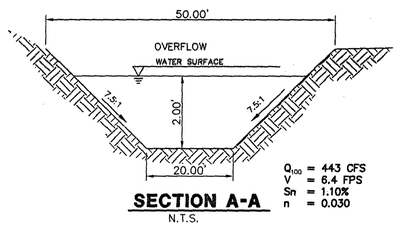
Project Name: FILING 1-F
Project No. 3216.06
Calculated By: MK
Checked By:
Date: 7/13/99

STREET	Design Point	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			
		Area Desig.	Area (Ac)	Runoff Coeff.	Tc (min)	C*A (Ac)	I (in/hr)	Q (cfs)	Tc (min)	C*A (Ac)	I (in/hr)	Q (cfs)	Slope (%)	Street Flow (cfs)	Design Flow (cfs)	Slope (%)	Pipe Size (inches)	Length (ft)	Velocity (fps)	Tt (min)	
	1	A	2.12	0.89	11.1	1.89	6.75	12.74													
	2	B	3.33	0.89	6.7	2.96	8.25	24.42													
	3	C	2.14	0.89	6.5	1.90	8.40	15.96													
	5	D	1.11	0.93	9.0	1.03	7.25	7.47													
	4	E	1.80	0.89	6.3	1.60	8.50	13.60													
	4	F	1.36	0.93	10.7	1.26	6.90	8.69													
	6	D1	0.64	0.93	5.1	0.60	8.95	5.37													



LEGEND

- SUB BASIN BOUNDARY
- F / 2.24 / .87 / .89 — SUB BASIN DESIGNATION; AREA IN ACRES/ RUNOFF COEFFICIENTS(5YR/100YR)
- 1 — DESIGN POINT (D.P.)
- FLOW ARROW
- PROPOSED STORM SEWER
- EXISTING STORM SEWER
- 5910 — EXISTING CONTOUR
- EXISTING STREAM
- D. E. — DRAINAGE EASEMENT



SECTION A-A
N.T.S.

5-YR SUMMARY RUNOFF TABLE

BASIN	DESIGN POINT	BASIN AREA (AC.)	DISCHARGE(CFS.)
A	1	2.12	5.10
B	2	3.33	9.60
C	3	2.14	6.24
D	5	1.11	4.30
E	4	1.80	5.30
F	4	1.36	3.30
D1	6	0.64	2.70

100-YR SUMMARY RUNOFF TABLE

BASIN	DESIGN POINT	BASIN AREA (AC.)	DISCHARGE(CFS.)
A	1	2.12	12.74
B	2	3.33	24.42
C	3	2.14	15.96
D	5	1.11	11.31
E	4	1.80	13.60
F	4	1.36	8.69
D1	6	0.64	5.37

ENGINEER'S STATEMENT

PREPARED UNDER MY DIRECT SUPERVISION FOR AND ON BEHALF OF JR ENGINEERING, LTD.

4/12/99

JAMES P. FITZMORRIS, P.E.
COLORADO REGISTERED PROFESSIONAL
ENGINEER NO. 28211

COLORADO REGISTERED PROFESSIONAL ENGINEER 28211

PHASE III DRAINAGE PLAN
HERITAGE HILLS FILING NO. 1-F
PROJECT NO. 3216.06
DATE 11/24/98 REV. 7/14/99
SHEET 1 OF 1

JR Engineering, Ltd.
6020 Greenwood Plaza Blvd.
Englewood, Colorado 80111
Tel. (303) 740-9393
FAX (303) 721-9019

ENGINEERING/PLANNING/SURVEYING

HUITT-ZOLLARS

HUITT-ZOLLARS, INC.
4582 South Ulster Street, Suite 1303
Denver, Colorado 80237
303.740.7325 phone • 303.224.9997 fax

Drainage Report and Erosion Control Plan

For

Commercial Federal Bank

Lincoln Avenue. & Heritage Hills Road
City of Lone Tree, CO

Prepared for:

Commercial Federal Bank
450 Regency Parkway
Omaha, Nebraska 68114
Mr. Rick Levine
(402) 827-2822 • phone (402) 827-2825 • fax

HOLLAND BASHAM ARCHITECTS
H B A

Holland Basham Architects
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Omaha, Nebraska 68132
Mr. John Deacy
(402) 551-0800 • phone (402) 551-2295• fax

Prepared by:

Robert J. Palmer, P.E. (CO. P.E. #36320)
Project Manager

COLORADO REGISTERED
ROBERT J. PALMER
36320
SEP 0 8 2003
PROFESSIONAL ENGINEER

HZI JN #: 16-0220-01
Date: August 27, 2003
File Name: h:\proj\160220\docs\drainage\drainagereport.doc

APPROVED

CERTIFICATION

This Drainage Report for the **COMMERCIAL FEDERAL BANK** was prepared by me (or under my direct supervision) in accordance with the provisions of the Douglas County *Storm Drainage Design and Technical Criteria*, as adopted by the City of Lone Tree, and was designed to comply with the provisions thereof. I understand that the City of Lone Tree does not and will not assume liability for drainage facilities designed by others.

Robert J. Palmer, P.E.
Registered Professional Engineer
State of Colorado No. 36320

FG 2002, LLC hereby certifies that the drainage facilities for Heritage Hills Filing No. 1-F shall be constructed according to the design presented in this report. I understand that Douglas County does not and will not assume liability for the drainage facilities designed and/or certified by my engineer and that Douglas County reviews drainage plans pursuant to Colorado Revised Statutes, Title 30, Article 28; but cannot, on behalf of Heritage Hills Filing No.1-F, guarantee the final drainage design review will absolve FG 2002, LLC and/or their successors and/or assigns of future liability for improper design. I further understand that approval of the Final Plat does not imply approval of my engineer's drainage design.

FG 2002, LLC
Name of Developer

manager
Authorized Signature

TABLE OF CONTENTS

HOLLAND BASHAM ARCHITECTS
H B A

1. INTRODUCTION

This report has been prepared to show that the development of Lot 5 and a portion of Lot 4 of Heritage Hills Filing No. 4F are in conformance with Phase III Drainage Report for Heritage Hills Filing No. 1-F as prepared July, 1999 by JR Engineering, LTD. This report will also act as the Erosion Control Report for this project.

2. GENERAL LOCATION AND DESCRIPTION

A Location

This facility will be located in Section 10, Township 6 South, Range 67 West, of the 6th Principal Meridian, in the City of Lone Tree, County of Douglas, and State of Colorado. More specifically, this project is located at Northwest corner of Lincoln Avenue and Heritage Hills Circle.

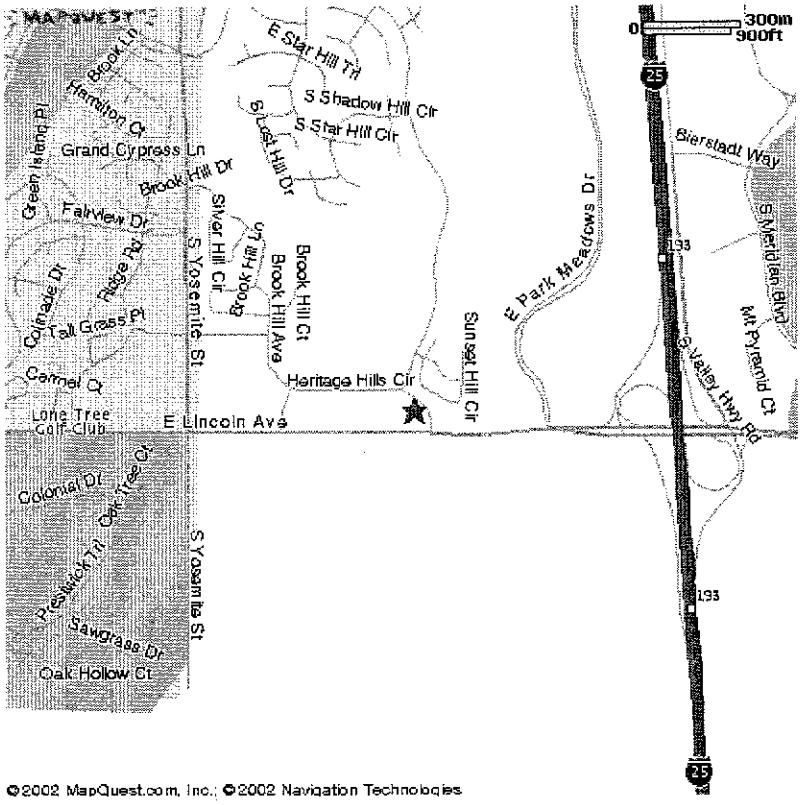


Figure 1 - Site Vicinity Map

B Description of Property

The total site (Lot 4 and Lot 5) is approximately 3.7 acres of which Commercial Federal is approximately 1.6 acres and is currently undeveloped. The site was previously used as agricultural and consists of native grasses. According the Conservation Service "Soils

Survey of Castle Rock Area, Colorado" the soil is Hydrologic Group C (Fondus clay loom and Renohill-Buick complex) which has moderately high runoff potential.

The proposed project consists of a single commercial building that will house a 3600 square-foot Commercial Federal Bank and a 1600 square-foot retail site.

3. DRAINAGE BASINS AND SUB-BASINS

A Major Basin Description

As shown in the approved Phase III Drainage Report for Heritage Hills Filing NO. 1-F, this site is located within the Willow Creek Watershed, which is tributary to Little Dry Creek, and is conveyed to the South Platte River. This site is located in Flood Zone X as shown on Flood Insurance Rate Map (FIRM) Community Panel Number 080049 0065C, revision date September 30, 1987. Flood zone X is described as "Areas determined to be outside 500-year flood plain".

B Sub-Basin Descriptions

Runoff from the project site currently flows from southwest to northeast. The runoff is then collected in shallow gutters in Heritage Hills Circle and then transferred to the underground storm sewer via a 20-footType R catch basin located in Heritage Hills Circle along the northerly edge of the property. Storm water runoff is then carried out of the catch basin by a 24-inch RCP and ultimately discharges into the regional detention facility. Per the JR Engineering Phase III Drainage Report, the existing 24-inch RCP carries a maximum flow of 22-cubic feet per second (cfs)

The proposed development will capture site runoff in shallow gutters where it will be transferred into the proposed site storm sewer via Type R catch basins. Storm runoff will then be transferred underground to the existing storm sewer in Heritage Hills Road and ultimately into the existing regional detention facility. The proposed storm sewer system will connect to the existing 20-foot Type R catch basin located in Heritage Hills circle.

4. DRAINAGE DESIGN CRITERIA

A Regulation/Criteria Used

Douglas County *Storm Drainage Design And Technical Criteria* (DCSDCM), the Urban Drainage and Flood Control District *Urban Storm Drainage Criteria Manual* (USDCM), the approved Phase III Drainage Report for Heritage Hills Filing 1-F and the Federal Emergency Management Agency *FIRM* were used in the preparation of this report. The criteria listed in the aforementioned manuals were without exceptions.

B Development Criteria Reference and Constraints

The 5-year recurrent storm event was used for the minor storm and the 100-year recurrent storm event was used for the major storm. All onsite drainage facilities are designed to properly convey runoff from the 100-year recurrent storm event per the existing Phase III Drainage Report for Heritage Hills Filing NO. 1-F. Rain fall intensities were taken from Figure 502A of the DCSDCM.

5. DRAINAGE FACILITY DESIGN

A General Concept

The proposed development will capture site runoff in shallow gutters where it will be transferred into the proposed site storm sewer via Type R catch basins connecting to an existing 20' Type R catch basin located along the northerly edge of the project. Runoff is collected in the catch basin and transferred to the existing underground detention basin via an existing 24-inch reinforced concrete pipe (RCP) and ultimately into the existing regional detention facility. As shown in the attached JR Engineering Phase III Drainage Report, the existing 24-inch RCP carries a maximum flow of 22-cubic feet per second (cfs). According the JR Report the storm sewer inlet is designed to capture all of the 5-year storm runoff and a portion of the 100-year storm runoff. The remainder of the 100-year runoff travels north along Heritage Hills Parkway and ultimately enters the underground storm sewer system. The 100-year site runoff entering the proposed onsite storm sewer system is approximately 22.1-cubic feet per second. Because the lowest proposed catch basin is approximately 3-feet higher than the existing catch basin the storm water runoff from the proposed development should not back up onto the project site. Storm runoff not captured in the existing inlet along, the northerly edge of the property, will travel north eventually being captured in existing storm sewer inlets along Heritage Hills Parkway and transferred into the existing underground storm sewer and eventually into the existing regional detention facility.

Appendix A of this report contains all of the calculations, tables, graphs and charts used in the preparation of this report.

B Specific Details

The Phase III Drainage Report for Heritage Hills Filing No. 1-F accounted for build out by using the percent impervious and runoff coefficients from the USDCM TABLE 3-1 for Commercial Areas. The proposed percent impervious and runoff coefficients for the developed portion of this project are much lower than shown in the Phase III Drainage Report for Heritage Hills Filing No. 1-F. The JR Engineering Report assumed future commercial development and used a 5-year storm runoff coefficient of 0.87 and a 100-year runoff coefficient of 0.89. The developed portion of the proposed site uses a weighted composite 5-year runoff coefficient of 0.43 and a 100-year runoff coefficient of 0.62. The

runoff coefficients from the JR Engineering Phase III Drainage Report were used for Basin E of this report because Basin E will not be developed as part of this project and the potential future development has not changed. The following table illustrates the total proposed runoff reaching the 20-foot Type R inlet located at the north edge of the project verses the runoff from the JR Engineering Report. However, it should be noted that there appears to be an error in the JR Engineering Phase III Drainage Report. In the 5-year Standard Form SF-3 Basin C shows a time of concentration of 6.5 minutes and a rainfall intensity o 3.35 in/hr. According to the rainfall intensity chart attached to that report the rainfall intensity should be approximately 4.35 in/hr. As such, the 5-year runoff from Basin C is likely higher than shown in that report.

Proposed Runoff
5-year recurrent storm interval runoff = 14.65 cfs
100-year recurrent storm interval runoff = 33.40 cfs

JR Engineering Report Runoff
5-year recurrent storm interval runoff = 14.84 cfs
100-year recurrent storm interval runoff = 38.25 cfs

6. CONCLUSION

This project is in compliance with the Douglas County *Storm Drainage Design And Technical Criteria*, *Criteria* (DCSDCM) as adopted by the City of Lone Tree and the Urban Drainage and Flood Control District *Urban Storm Drainage Criteria Manual* (USDCM). This project is in compliance with the approved Phase III Drainage Report for Heritage Hills Filing No. 1-F.

7. EROSION CONTROL

The project site is to be protected from erosion at all time during construction and landscaping per Section A.11 of the Douglas County Storm Drainage Design And Technical Criteria Addendum A (DCSDDTCA). Per Table A.11.1 of the DCSDDTCA 34-Cubic Yards of sediment trap retention is required (400-feet at 4% = 16-cubic yards per acres at 2.13 acres) However, current site grading and the proposed site grading do not drain storm water runoff to a central area. As such, it is not practical to install sediment traps on this site. To contain sediment onsite a silt fence will be installed around the grading area in a manner that restricts sediment from reaching public streets or drainage facilities. Hay bale filters are to be installed around all storm sewer inlets associated with this project during grading. After pavement of the project is completed the hay bale inlet protection will be replaced with gravel inlet protection as shown on the Erosion Control Plan located in the map pocket of this report. Estimated construction time for this project is 120 days.

Section A.11 of the DCSDDTCA is included in Appendix C of this report.

Landscape areas shall be replanted immediately or protected with straw until weather permits replanting.

During grading exposed ground should be watered regularly to sufficiently control air born erosion.

REFERENCES

Flood Insurance Rate Map (FIRM), Federal Emergency Management Agency (FEMA) Community Panel Number 080049 0065 C, Map revision Date September 30, 1987.

Phase III Drainage Report for Heritage Hills Filing No. 1-F, JR Engineering, LTD July, 1999.

Storm Drainage Design and Technical Criteria, Douglas County January, 1986.

Storm Drainage Design and Technical Criteria Addendum A, Douglas County January, 1992

Urban Storm Drainage Criteria Manual, Urban Drainage and Flood Control District June, 2001.

Appendix A – Calculations

RATIONAL METHOD CALCULATIONS

DESIGN POINT 5

Contributing Sub-Basins: E

TIME OF CONCENTRATION

use 5.0 minute minimum

t_c = 4.9 MINUTES From Form SF-2

PEAK RUNOFF

Q = CIA (Equation RO-1)

% impervious= 95.00

C_5 = 0.87 From Table RO-5

C_{100} = 0.89 From Table RO-5

Rain Fall Intensity taken from Figure 502A

I_5 = 4.90 IN./HR

I_{100} = 9.00 IN./HR

A = 1.949 ACRE

Q_5 = 8.31 CFS

Q_{100} = 15.61 CFS

Inlet Calculations

$Q=C_wL_wd^{1.5}$

Q= 15.61 cfs

C_w 3.00

L_w ?

d 0.5 feet

L_w= 14.72 feet

USE 15' MINIMUM TYPE R CATCH BASIN

STANDARD FORM SF-2
TIME OF CONCENTRATION YEAR

SUBDIVISION: Commercial Federal Bank - Lone Tree

CALCULATED BY: Robert Palmer **DATE:** 04/08/03 $t_c = t_i + t_t$

SUB-BASIN DATA			INITIAL / OVERLAND TIME (t_i)			TRAVEL TIME (t_t)				t_c CHECK (URBANIZED BASINS)			FINAL t_c	REMARKS
DESIGN (1)	AREA Ac (2)	C_5 (3)	LENGTH Ft (4)	SLOPE % (5)	t_i Min (6)	LENGTH Ft (7)	SLOPE % (8)	VEL FPS (9)	t_t Min (10)	COMP t_c (11)	TOTAL LENGTH (12)	t_c=(L/180)+10 Min (13)	Min (14)	
1	0.576	0.39	148	3.9	9.9	37	1	2.0	0.3	10.2	185	11.0	10.2	
2	0.379	0.44	80	7.9	5.3	75	1	2.0	0.6	6.0	155	10.9	6.0	
3	0.278	0.52	52	2.9	5.3	85	2.4	3.1	0.5	5.7	137	10.8	5.7	
4	0.186	0.47	50	4	5.1	50	5	4.4	0.2	5.2	100	10.6	5.2	
5	1.949	0.87	359	4.7	4.7	32	1.8	2.8	0.2	4.9	391	12.2	4.9	use 5.0 minute min
6	0.609	0.16	110	4.9	10.4	11	1	2.0	0.1	10.5	121	10.7	10.5	

STANDARD FORM SF-3
STORM DRAINAGE SYSTEM DESIGN
(Rational Method Procedure)

SUBDIVISION: Commercial Federal Bank - Lone Tree

CALCULATED BY: Robert Palmer **DATE:** 04/10/03

DESIGN STORM: 5-Yr

	STREET	DESIGN POINT	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
			AREA DESIGN	AREA (AC)	RUNOFF COEFF	t_c (MIN)	C*A (AC)	i (IN/HR)	Q (CFS)	t_c (MIN)	Σ (C*A) (AC)	i (IN/HR)	Q (CFS)	SLOPE (%)	STREET FLOW	DESIGN FLOW	SLOPE (%)	PIPE SIZE	LENGTH (FT)	VELOCITY (FPS)	t_t (MIN)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
1		1	A	0.58	0.39	10.2	0.22	3.80	0.85				0.85									
2		2	B	0.38	0.44	6.0	0.17	4.35	0.73				0.73									
3		3	C	0.28	0.52	5.7	0.14	4.40	0.64				1.36									
4		4	D	0.19	0.47	5.2	0.09	4.90	0.43				1.28									
5		5	E	1.95	0.87	4.9	1.70	4.90	8.31				8.31									
6		6	G	0.60	0.16	10.5	0.10	4.10	0.39				14.65									
7	Basin F from JR Report								3.30													
8																						
9																						
10																						
11																						
12																						
13																						
14																						

STANDARD FORM SF-3
STORM DRAINAGE SYSTEM DESIGN
(Rational Method Procedure)

SUBDIVISION: Commercial Federal Bank - Lone Tree

CALCULATED BY: Robert Palmer **DATE:** 04/10/03

DESIGN STORM: 100-Yr

	STREET	DESIGN POINT	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
			AREA DESIGN	AREA (AC)	RUNOFF COEFF	t_c (MIN)	C*A (AC)	i (IN/HR)	Q (CFS)	t_c (MIN)	Σ (C*A) (AC)	i (IN/HR)	Q (CFS)	SLOPE (%)	STREET FLOW	DESIGN FLOW	SLOPE (%)	PIPE SIZE	LENGTH (FT)	VELOCITY (FPS)	t_t (MIN)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
1		1	A	0.58	0.60	10.2	0.35	7.00	2.42				2.42									
2		2	B	0.38	0.62	6.0	0.23	8.25	1.94				1.94									
3		3	C	0.28	0.67	5.7	0.19	8.30	1.55				3.48									
4		4	D	0.19	0.63	5.2	0.12	8.80	1.03				3.45									
5		5	E	1.95	0.89	4.9	1.73	9.00	15.61				15.61									
6		6	G	0.61	0.50	10.5	0.30	7.10	2.16				33.40									
7	Basin F from JR Report								8.69													
8																						
9																						
10																						
11																						
12																						
13																						
14																						

Lateral C-1 100-Year
Worksheet for Circular Channel

Project Description	
Project File	c:\haestad\fmw\project1.fm2
Worksheet	CFB - Lone Tree, Colorado
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.009	
Channel Slope	0.038000	ft/ft
Diameter	15.00	in
Discharge	15.61	cfs

Results		
Depth	0.89	ft
Flow Area	0.94	ft^2
Wetted Perimeter	2.52	ft
Top Width	1.13	ft
Critical Depth	1.24	ft
Percent Full	71.36	
Critical Slope	0.025828	ft/ft
Velocity	16.66	ft/s
Velocity Head	4.31	ft
Specific Energy	5.21	ft
Froude Number	3.23	
Maximum Discharge	19.57	cfs
Full Flow Capacity	18.19	cfs
Full Flow Slope	0.027991	ft/ft
Flow is supercritical.		

Lateral C-1 5-Year
Worksheet for Circular Channel

Project Description	
Project File	c:\haestad\fmw\project1.fm2
Worksheet	CFB - Lone Tree, Colorado
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.009	
Channel Slope	0.038000	ft/ft
Diameter	15.00	in
Discharge	8.31	cfs

Results		
Depth	0.59	ft
Flow Area	0.57	ft^2
Wetted Perimeter	1.90	ft
Top Width	1.25	ft
Critical Depth	1.13	ft
Percent Full	47.44	
Critical Slope	0.006964	ft/ft
Velocity	14.49	ft/s
Velocity Head	3.26	ft
Specific Energy	3.85	ft
Froude Number	3.77	
Maximum Discharge	19.57	cfs
Full Flow Capacity	18.19	cfs
Full Flow Slope	0.007933	ft/ft
Flow is supercritical.		

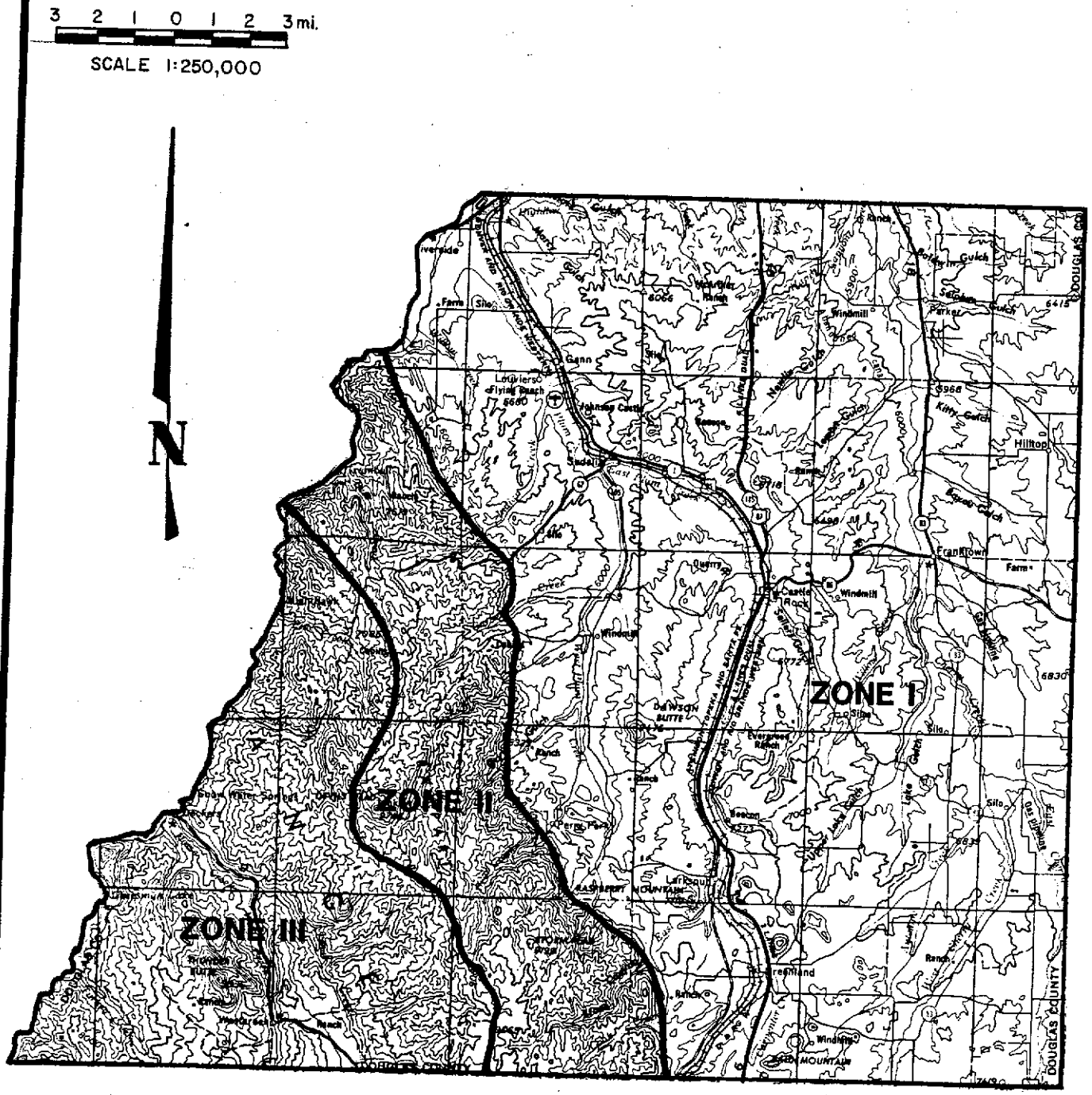
TABLE RO-5

Runoff Coefficients, C

Percentage Imperviousness	Type C and D NRCS Hydrologic Soil Groups					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0%	0.04	0.15	0.25	0.37	0.44	0.50
5%	0.08	0.18	0.28	0.39	0.46	0.52
10%	0.11	0.21	0.30	0.41	0.47	0.53
15%	0.14	0.24	0.32	0.43	0.49	0.54
20%	0.17	0.26	0.34	0.44	0.50	0.55
25%	0.20	0.28	0.36	0.46	0.51	0.56
30%	0.22	0.30	0.38	0.47	0.52	0.57
35%	0.25	0.33	0.40	0.48	0.53	0.57
40%	0.28	0.35	0.42	0.50	0.54	0.58
45%	0.31	0.37	0.44	0.51	0.55	0.59
50%	0.34	0.40	0.46	0.53	0.57	0.60
55%	0.37	0.43	0.48	0.55	0.58	0.62
60%	0.41	0.46	0.51	0.57	0.60	0.63
65%	0.45	0.49	0.54	0.59	0.62	0.65
70%	0.49	0.53	0.57	0.62	0.65	0.68
75%	0.54	0.58	0.62	0.66	0.68	0.71
80%	0.60	0.63	0.66	0.70	0.72	0.74
85%	0.66	0.68	0.71	0.75	0.77	0.79
90%	0.73	0.75	0.77	0.80	0.82	0.83
95%	0.80	0.82	0.84	0.87	0.88	0.89
100%	0.89	0.90	0.92	0.94	0.95	0.96
	Type B NRCS Hydrologic Soils Group					
0%	0.02	0.08	0.15	0.25	0.30	0.35
5%	0.04	0.10	0.19	0.28	0.33	0.38
10%	0.06	0.14	0.22	0.31	0.36	0.40
15%	0.08	0.17	0.25	0.33	0.38	0.42
20%	0.12	0.20	0.27	0.35	0.40	0.44
25%	0.15	0.22	0.30	0.37	0.41	0.46
30%	0.18	0.25	0.32	0.39	0.43	0.47
35%	0.20	0.27	0.34	0.41	0.44	0.48
40%	0.23	0.30	0.36	0.42	0.46	0.50
45%	0.26	0.32	0.38	0.44	0.48	0.51
50%	0.29	0.35	0.40	0.46	0.49	0.52
55%	0.33	0.38	0.43	0.48	0.51	0.54
60%	0.37	0.41	0.46	0.51	0.54	0.56
65%	0.41	0.45	0.49	0.54	0.57	0.59
70%	0.45	0.49	0.53	0.58	0.60	0.62
75%	0.51	0.54	0.58	0.62	0.64	0.66
80%	0.57	0.59	0.63	0.66	0.68	0.70
85%	0.63	0.66	0.69	0.72	0.73	0.75
90%	0.71	0.73	0.75	0.78	0.80	0.81
95%	0.79	0.81	0.83	0.85	0.87	0.88
100%	0.89	0.90	0.92	0.94	0.95	0.96

STORM DRAINAGE DESIGN AND TECHNICAL CRITERIA

FIGURE 501



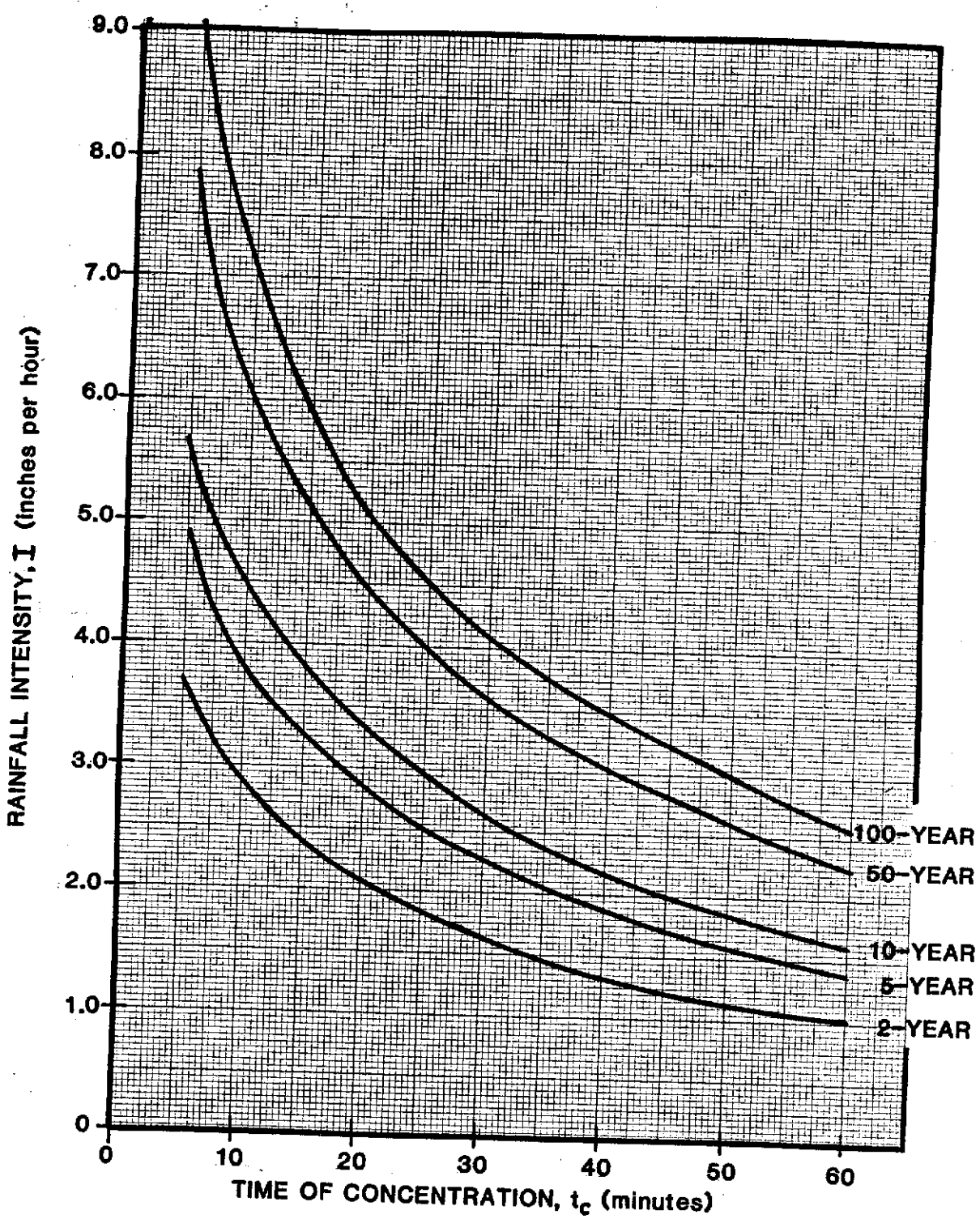
RAINFALL ZONES

Date: NOV 1984
Rev:

REFERENCE: WRC TM-1, 5-24-84

DCSDDTC

TIME - INTENSITY - FREQUENCY CURVES
ZONE I



Date: NOV 1984
Rev:

REFERENCE: WRC TM-1 , 5-24-1984

TABLE ST-7

Sag Inlet Discharge Variables and Coefficients
(Modified From Akan and Houghtalen 2002)

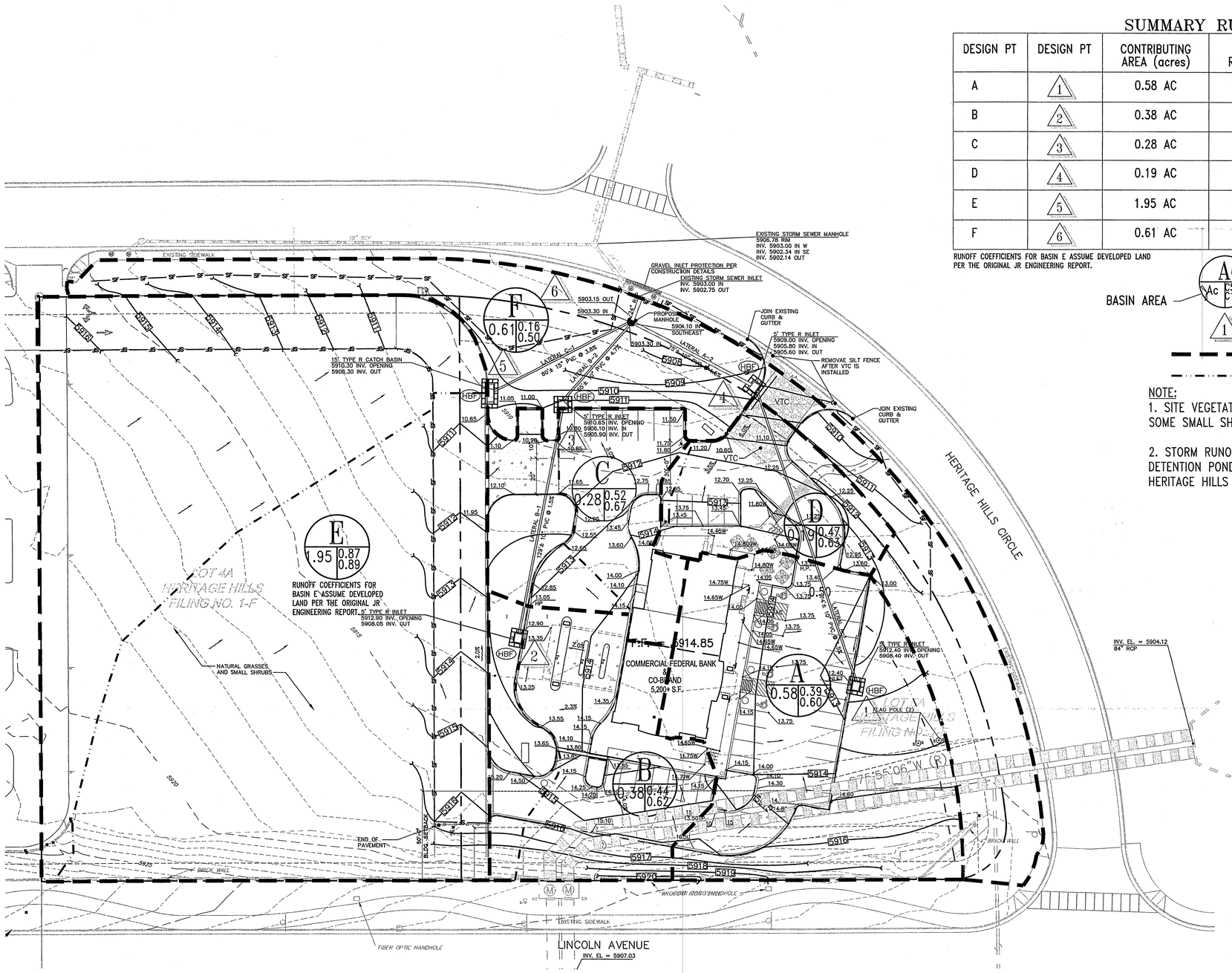
Inlet Type	C_w	L_w[1]	Weir Equation Valid For	Definitions of Terms
Grate Inlet	3.00	$L + 2W$	$d < 1.79(A_o/L_w)$	L = Length of grate W = Width of grate d = Depth of water over grate A_0= Clear opening area[2]
Curb Opening Inlet	3.00	L	$d < h$	L = Length of curb opening h = Height of curb opening $d = d_i - (h/2)$ d_i = Depth of water at curb opening
Depressed Curb Opening Inlet[3]	2.30	$L + 1.8W$	$d < (h + a)$	W = Lateral width of depression a = Depth of curb depression
Slotted Inlets	2.48	L	$d < 0.2$ ft	L = Length of slot d = Depth at curb

1 The weir length should be reduced where clogging is expected.
2 Ratio of clear opening area to total area is 0.8 for P-1-7/8-4 and reticuline grates, 0.9 for P-1-7/8 and 0.6 for P-1-1/8 grates. Curved vane and tilt bar grates are not recommended at sag locations.
3 If $L > 12$ ft, use the expressions for curb opening inlets without depression.

	C_o	A_0[4]	Orifice Equation Valid for	Definition of Terms
Grate Inlet	0.67	Clear opening area[5]	$d > 1.79(A_o/L_w)$	d = Depth of water over grate
Curb Opening Inlet (depressed or undepressed, horizontal orifice throat[6])	0.67	$(h)(L)$	$d_i > 1.4h$	$d = d_i - (h/2)$ d_i = Depth of water at curb opening h = Height of curb opening
Slotted Inlet	0.80	$(L)(W)$	$d > 0.40$ ft	L = Length of slot W = Width of slot d = Depth of water over slot

4 The orifice area should be reduced where clogging is expected.
5 The ratio of clear opening area to total area is 0.8 for P-1-7/8-4 and reticuline grates, 0.9 for P-1-7/8 and 0.6 for P-1-1/8 grates. Curved vane and tilt bar grates are not recommended at sag locations.
6 See Figure ST-5 for other types of throats.

3.3.6 Inlet Clogging. Inlets are subject to clogging effects (see Photographs ST-5 and ST-6). Selection of a clogging factor reflects the condition of debris and trash on the street. During a storm event, street inlets are usually loaded with debris by the first-flush runoff volume. As a common practice for street drainage, 50% clogging is considered for the design of a single grate inlet and 10% clogging is considered for a single curb-opening inlet. Often, it takes multiple units to collect the stormwater on the



SUMMARY RUNOFF TABLE

DESIGN PT	DESIGN PT	CONTRIBUTING AREA (acres)	5-YEAR RUNOFF (cfs)	100-YEAR PEAK RUNOFF (cfs)
A	1	0.58 AC	0.85 CFS	2.42 CFS
B	2	0.38 AC	0.73 CFS	1.94 CFS
C	3	0.28 AC	0.64 CFS	1.55 CFS
D	4	0.19 AC	0.43 CFS	1.03 CFS
E	5	1.95 AC	8.31 CFS	15.61 CFS
F	6	0.61 AC	0.40 CFS	2.16 CFS

RUNOFF COEFFICIENTS FOR BASIN E ASSUME DEVELOPED LAND PER THE ORIGINAL JR ENGINEERING REPORT.

BASIN AREA — A / Ac | C5 / C100 — BASIN DESIGNATION; 5YR COMPOSITE 'C'; 100YR COMPOSITE 'C'

1 — DESIGN POINT

BASIN LIMITS

TIME OF CONCENTRATION

NOTE:

1. SITE VEGETATION CONSIST OF NATIVE GRASSES AND SOME SMALL SHRUBS.

2. STORM RUNOFF FROM SITE IS DETAINED IN A REGIONAL DETENTION POND PER THE PHASE III DRAINAGE REPORT FOR HERITAGE HILLS FILING NO. 1-F

STORM SEWER PIPE FLOW

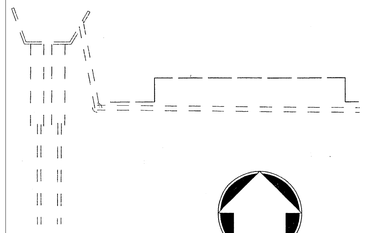
LATERAL A-1
Q(full pipe flow) = 3.9 CFS.
Q100-year = 2.4 CFS (57% of full pipe flow)
100-year velocity = 7.5 FT/SEC
Q5-year = 0.9 CFS (32% of full pipe flow)
5-year velocity = 5.7 FT/SEC

LATERAL A-2
Q(full pipe flow) = 3.9 CFS.
Q100-year = 3.4 CFS (74% of full pipe flow)
100-year velocity = 8.0 FT/SEC
Q5-year = 1.3 CFS (40% of full pipe flow)
5-year velocity = 6.4 FT/SEC

LATERAL B-1
Q(full pipe flow) = 3.9 CFS.
Q100-year = 1.9 CFS (50% of full pipe flow)
100-year velocity = 7.1 FT/SEC
Q5-year = 0.7 CFS (29% of full pipe flow)
5-year velocity = 5.5 FT/SEC

LATERAL B-2
Q(full pipe flow) = 6.9 CFS.
Q100-year = 3.3 CFS (50% of full pipe flow)
100-year velocity = 12.6 FT/SEC
Q5-year = 1.4 CFS (30% of full pipe flow)
5-year velocity = 9.8 FT/SEC

LATERAL C-1
Q(full pipe flow) = 18.2 CFS.
Q100-year = 15.6 CFS (71% of full pipe flow)
100-year velocity = 16.9 FT/SEC
Q5-year runoff = 8.3 CFS (47% of full pipe flow)
5-year velocity = 16.7 FT/SEC



IF YOU DIG COLORADO – CALL US FIRST!
UTILITIES NOTIFICATION CENTER
1-800-922-1987
CALL 2 BUSINESS DAYS PRIOR TO EXCAVATION FOR UTILITY LOCATIONS

30 0 15 30
1 inch = 30 ft.

CLIENT:
COMMERCIAL FEDERAL BANK
LINCOLN AVE. & HERITAGE HILLS CIRCLE
LONE TREE, COLORADO

OTHER TEAM MEMBER:
HOLLAND BASHAM ARCHITECTS
HBA
1111 SOUTH 48th AVENUE
OMAHA, NEBRASKA 68132
(402) 551-0800

CIVIL ENGINEER:
HUITT-ZOLLARS
HUITT-ZOLLARS, INC.
4582 SOUTH ULSTER ST. SUITE 1303
DENVER, COLORADO 80237
Phone: (303) 740-7325
Fax: (303) 224-9997
EMAIL: wbryant@huitt-zollars.com

NO.	DATE	REVISION DESCRIPTION

PREPARED UNDER THE DIRECT SUPERVISION OF:
SEAL:
ROBERT J. PALMER, P.E. (CO PE #36320)
FOR AND ON BEHALF OF HUITT-ZOLLARS, INC.

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DEVELOPMENT INFORMATION:
REDEVELOPMENT
MIXED USE COMMERCIAL WITHIN A SINGLE STRUCTURE.

SITE ADDRESS:
COMMERCIAL FEDERAL BANK
NORTHWEST CORNER OF HERITAGE HILL CIRCLE AND LINCOLN AVENUE
CITY OF LONE TREE, CO

SCALE:	1"=30'	HZI PIC:	WAB
DATE:	8/27/03	HZI PM:	RJP
DESIGNED BY:	RJP	HZI QA/QC:	GP
DRAWN BY:	LX	FILE NAME:	EROSION.DWG
CHECKED BY:	WB	HZI JN:	16-0220-01

DRAWING TITLE:
PROPOSED BASIN CONDITIONS

SHEET NO:
B-1

APPROVED

Farnsworth GROUP

Weighted Imperviousness

Job Name: APMI - Lone Tree

Date: 12/19/23

By: JMN

Land Use or Surface Characteristics	I	C_5	C_{100}
[1, 3] Landscape	0	0.15	0.50
[1, 3] Roof	90	0.75	0.83
[1, 3] Drives and Walks	90	0.75	0.83
[2, 4] Business:			
[2, 4] Commercial Areas	(95)	0.87	0.89
[2, 4] Streets:			
[2, 4] Paved	(100)	0.89	0.93
[5, 6, 7] Undeveloped Areas:			
[5, 6, 7] Historic flow analysis	2	0.05	0.49
[5, 6, 7] Off-site flow analysis	45	0.40	0.67
[5, 6, 7] Streets:			
[5, 6, 7] Paved	100	0.85	0.89
[5, 6, 7] Drive and walks	90	0.77	0.85
[5, 6, 7] Roofs	90	0.77	0.85
[5, 6, 7] Lawns, clayey soil	2	0.05	0.49

[1] % Impervious & Runoff Coefficient from Lot 5A REPORT (References UDFCD, *USDCM Vol. 1* , Table RO-5, June 2001)

[2] (% Impervious assumed from corollary coefficient); Runoff Coeffecient from JR REPORT (References UDFCD, *USDCM* , Table 3-1 (42), November 1990), except C_5 reference for "Streets: Paved" = 0.88

[3] Lot 5A REPORT indicates site soil as "…Hydrologic Group C (Fondus [sic] clay loom [sic] and Renohill-Buick complex)…" as referenced to the "…Conservation Service 'Soils Survey of Castle Rock Area, Colorado'…"

[4] JR REPORT indicates site soil as "…Hydrologic Soil Group C (Fondis clay loam and Renohill-Buick complex…" as referenced to the "…Soil Conservation Service 'Soil Survey of Castle Rock Area, Colorado'…" revised November 1974

[5] % Impervious from MHFD, *USDCM Vol. 1* , Table 6-3, current edition

[6] Runoff Coefficient from MHFD, *USDCM Vol. 1* , Table 6-5, current edition (assuming Hydrologoc Soil Group Rating D)[7]

[7] USDA, Natural Resources Conservation Service, Web Soil Survey, current edition, identifies the site as 36.5% Newlin-Santana complex, 5 to 20 percent slopes (NsE), Hydrologic Soil Group Rating B and as 63.5% Renohill-Buick complex, 5 to 25 percent slopes (RmE), Hydrologic Soil Group Rating D

EXISTING SITE

Basin	Commercial (Basin E)	(Basin F)	Total	[8]Weighted Runoff Coeff I	C_5	C_{100}
A	0.560		0.560	95	0.870	0.890
R	0.077		0.077	95	0.870	0.890
O1a	0.614		0.614	95	0.870	0.890
O1b		0.003	0.003	1.77	0.160	0.500
O1c	0.144		0.144	95	0.870	0.890
O2	0.110		0.110	95	0.870	0.890
O3	0.044		0.044	95	0.870	0.890
O4	0.398		0.398	95	0.870	0.890
Total	1.947	0.003	1.950	95	0.870	0.890

PROPOSED SITE

Basin	Lawns	Drive/walks	Roofs	Commercial (Basin E)	(Basin F)	Total	[8]Weighted Runoff Coeff I	C_5	C_{100}	
A	0.156	0.404				0.560	65	0.572	0.752	[5, 6, 7]
R			0.077			0.077	90	0.773	0.853	[5, 6, 7]
O1a				0.614		0.614	95	0.870	0.890	[2, 4]
O1b					0.003	0.003	1.77	0.160	0.500	[1, 3]
O1c	0.138	0.006				0.144	6	0.083	0.508	[5, 6, 7]
O2				0.110		0.110	95	0.870	0.890	[2, 4]
O3a	0.032					0.032	2	0.051	0.492	[5, 6, 7]
O3b	0.006					0.006	2	0.051	0.492	[5, 6, 7]
O3c	0.006					0.006	2	0.051	0.492	[5, 6, 7]
O4				0.398		0.398	95	0.870	0.890	[2, 4]
O4 1				*0.070*		*0.070*	*95*	*0.870*	*0.890*	[2, 4]
O4 2				*0.074*		*0.074*	*95*	*0.870*	*0.890*	[2, 4]
Total	0.338	0.410	0.077	1.122	0.003	1.950	78	0.671	0.802	

[8] Runoff Coefficient from MHFD, *USDCM Vol. 1* , Table 6-4, current edition

Farnsworth GROUP

Time of Concentration

Job Name: APMI - Lone Tree

Date: 12/19/23

Calculated by: JMN

EXISTING SITE

Sub-Basin Data			Initial/Overland Time (Ti)			Travel Time Tt				Tc Check Urbanized Basin		Final Tc	Remarks
Desig	C5	Area Ac	Length Ft	Slope Ft/Ft	Ti Min	Length Ft	Slope Ft/Ft	[1]K	Tt Min	Tot Len Ft	Tc Min	Min	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
A	0.87	0.560	45	0.160	1.1								
	0.87	0.560	165	0.035	3.5					210	10.5	5.0	
R	0.87	0.077										5.0	Min. per CRITERIA
O1a	0.87	0.614										5.0	LOT 5 REPORT (Basin E)
O1b	0.16	0.003										5.0	LOT 5 REPORT (Basin E)
O1c	0.87	0.144										5.0	LOT 5 REPORT (Basin E)
O2	0.87	0.110										5.0	LOT 5 REPORT (Basin E)
O3	0.87	0.044										5.0	LOT 5 REPORT (Basin E)
O4	0.87	0.398										5.0	LOT 5 REPORT (Basin E)

PROPOSED SITE

Sub-Basin Data			Initial/Overland Time (Ti)			Travel Time Tt				Tc Check Urbanized Basin		Final [5,6,7]Tc	Remarks
Desig	C5	Area Ac	Length Ft	Slope Ft/Ft	[1]Ti Min	Length Ft	Slope Ft/Ft	[2]K	[3]Tt Min	Tot Len Ft	[4]Tc Min	Min	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
A	0.57	0.560	19	0.250	1.4								
	0.57	0.560	30	0.020	4.2								
						115	0.006	20	1.2				
						133	0.020	20	0.8	297	16.5	7.6	
R	0.77	0.077										5.0	Min. per CRITERIA
O1a	0.87	0.614										5.0	LOT 5 REPORT (Basin E)
O1b	0.16	0.003										5.0	LOT 5 REPORT (Basin E)
O1c	0.08	0.144										5.0	Min. per CRITERIA
O2	0.87	0.110										5.0	LOT 5 REPORT (Basin E)
O3a	0.05	0.032										5.0	Min. per CRITERIA
O3b	0.05	0.006										5.0	Min. per CRITERIA
O3c	0.05	0.006										5.0	Min. per CRITERIA
O4	0.87	0.398										5.0	LOT 5 REPORT (Basin E)
$O4_1$	0.87	0.070										5.0	Min. per CRITERIA
$O4_2$	0.87	0.074										5.0	Min. per CRITERIA

[1]USDCM, Equation 6-3

[2]USDCM, Table 6-2

[3]USDCM, Equation 6-4

[4]USDCM, Equation 6-5

[5]USDCM, Equation 6-2

[6]Minimum t_c, CRITERIA, Section 6.3.2

[7]t_c shall be lesser of USDCM Equation 6-2 and USDCM Equation 6-5; USDCM, Vol. 1, Chapter 6, Section 2.4.3

Farnsworth GROUP

Stormwater Runoff

Job Name: APMI - Lone Tree

Date: 12/19/23
Calculated by: JMN
Design Storm: 5-yr

EXISTING SITE

Design Point	Direct Runoff							Total Runoff				Street		Pipe			Travel Time			Remarks
	Area Desig	Area (Ac)	Runoff Coeff	Tc (min)	CA	I[1] (in/hr)	Q (cfs)	Tc (min)	Total CA	I[1] (in/hr)	Q (cfs)	Slope %	Street Flow	Design Flow	Slope %	Pipe Size	Length (Ft)	Vel (fps)	Tt (min)	
	A	0.56	0.87	5.0	0.49	4.85	2.36													to DP 11
	R	0.08	0.87	5.0	0.07	4.85	0.32													to DP 11
	O1a	0.61	0.87	5.0	0.53	4.85	2.59													to DP 11
12	O1b	0.00	0.16	5.0	0.00	4.85	0.00													to MS4
	O1c	0.14	0.87	5.0	0.13	4.85	0.61													to DP 11
	O2	0.11	0.87	5.0	0.10	4.85	0.47													to DP 11
	O3	0.04	0.87	5.0	0.04	4.85	0.18													to DP 11
	O4	0.40	0.87	5.0	0.35	4.85	1.68													to DP 11
11								5.0	1.69	4.85	8.22									to MS4
								5.0	1.69	4.85	8.22									to MS4

PROPOSED SITE

Design Point	Direct Runoff							Total Runoff				Street		Pipe			Travel Time			Remarks
	Area Desig	Area (Ac)	Runoff Coeff	Tc (min)	CA	I[1] (in/hr)	Q (cfs)	Tc (min)	Total CA	I[1] (in/hr)	Q (cfs)	Slope %	Street Flow	Design Flow	Slope %	Pipe Size (ft)	Length (ft)	Vel (fps)	Tt (min)	
	A	0.56	0.57	7.6	0.32	4.35	1.39													to DP 1
2	R	0.08	0.77	5.0	0.06	4.85	0.29							0.29	0.5	1	250	0.37	11.4	to DP 3
5	*O4 1*	0.07	0.87	5.0	0.06	4.85	0.30													to DP 6
	O3a	0.03	0.05	5.0	0.00	4.85	0.01													to DP 6
6								5.0	0.06	4.85	0.31	[2](varies)	0.31						7.6	to DP 1
1								12.6	0.38	3.50	1.34									
							(	12.6	0.06	3.50	0.22	)								to DP 10
							(	12.6	0.32	3.50	1.12	)								to DP 3
3								12.6	0.38	3.50	1.33									to DP 4
7	O3b	0.01	0.05	5.0	0.00	4.85	0.00													to DP 10
	O1c	0.14	0.08	5.0	0.01	4.85	0.06													to DP 4
4								12.6	0.39	3.50	1.37			1.37	0.50	1.00	140	1.75	1.3	to DP 11
10								12.6	0.45	3.50	1.59									to DP 11
8	*O4 2*	0.07	0.87	5.0	0.06	4.85	0.31													to DP 9
	O3c	0.01	0.05	5.0	0.00	4.85	0.00													to DP 9
9								5.0	0.06	4.85	0.31	[3](n/a)								to DP 11
	O1a	0.61	0.87	5.0	0.53	4.85	2.59													to DP 11
	O2	0.11	0.87	5.0	0.10	4.85	0.47													to DP 11
11								13.9	1.15	3.45	3.97									to MS4
12	O1b	0.00	0.16	5.0	0.00	4.85	0.00													to MS4
								13.9	1.15	3.45	3.97									to MS4

[1]Intensity from CRITERIA, Figure 6-2
[2]Slope varies; see Tc calculations for Tt
[3]Tt for Basin O1a is assumed 5.0 min. minimum per LOT 5 REPORT

Farnsworth GROUP

Stormwater Runoff

Job Name: APMI - Lone Tree

Date: 12/19/23
Calculated by: JMN
Design Storm: 100-yr

EXISTING SITE

	Direct Runoff							Total Runoff				Street		Pipe			Travel Time			
Design Point	Area Desig	Area (Ac)	Runoff Coeff	Tc (min)	CA	I[1] (in/hr)	Q (cfs)	Tc (min)	Total CA	I[1] (in/hr)	Q (cfs)	Slope %	Street Flow	Design Flow	Slope %	Pipe Size	Length (Ft)	Vel (fps)	Tt (min)	Remarks
	A	0.56	0.89	5.0	0.50	8.80	4.39													to DP 11
	R	0.08	0.89	5.0	0.07	8.80	0.60													to DP 11
	O1a	0.61	0.89	5.0	0.55	8.80	4.81													to DP 11
12	O1b	0.00	0.50	5.0	0.00	8.80	0.01													to MS4
	O1c	0.14	0.89	5.0	0.13	8.80	1.13													to DP 11
	O2	0.11	0.89	5.0	0.10	8.80	0.86													to DP 11
	O3	0.04	0.89	5.0	0.04	8.80	0.34													to DP 11
	O4	0.40	0.89	5.0	0.35	8.80	3.12													to DP 11
11								5.0	1.73	8.80	15.25									to MS4
								5.0	1.73	8.80	15.26									to MS4

PROPOSED SITE

	Direct Runoff							Total Runoff				Street		Pipe			Travel Time			
Design Point	Area Desig	Area (Ac)	Runoff Coeff	Tc (min)	CA	I[1] (in/hr)	Q (cfs)	Tc (min)	Total CA	I[1] (in/hr)	Q (cfs)	Slope %	Street Flow	Design Flow	Slope %	Pipe Size (ft)	Length (ft)	Vel (fps)	Tt (min)	Remarks
	A	0.56	0.75	7.6	0.42	7.90	3.33													to DP 1
2	R	0.08	0.85	5.0	0.07	8.80	0.57							0.57	0.5	1	250	0.73	5.7	to DP 3
5	*O4 1*	0.07	0.89	5.0	0.06	8.80	0.55													to DP 6
	O3a	0.03	0.49	5.0	0.02	8.80	0.14													to DP 6
6								5.0	0.08	8.80	0.69	[2](varies)	0.69						7.6	to DP 1
1								12.6	0.50	6.40	3.20									
							(	12.6	0.08	6.40	0.50	)								to DP 10
							(	12.6	0.42	6.40	2.70	)								to DP 3
3								12.6	0.49	6.40	3.12									to DP 4
7	O3b	0.01	0.49	5.0	0.00	8.80	0.03													to DP 10
	O1c	0.14	0.51	5.0	0.07	8.80	0.65													to DP 4
4								12.6	0.56	6.40	3.59			3.59	0.50	1.00	140	4.57	0.5	to DP 11
10								12.6	0.64	6.40	4.11									to DP 11
8	*O4 2*	0.07	0.89	5.0	0.07	8.80	0.58													to DP 9
	O3c	0.01	0.49	5.0	0.00	8.80	0.02													to DP 9
9								5.0	0.07	8.80	0.60	[3](n/a)								to DP 11
	O1a	0.61	0.89	5.0	0.55	8.80	4.81													to DP 11
	O2	0.11	0.89	5.0	0.10	8.80	0.86													to DP 11
11								13.1	1.35	6.30	8.53									to MS4
12	O1b	0.00	0.50	5.0	0.00	8.80	0.01													to MS4
								13.1	1.36	6.30	8.54									to MS4

[1]Intensity from CRITERIA, Figure 6-2

[2]Slope varies; see Tc calculations for Tt

[3]Tt for Basin O1a is assumed 5.0 min. minimum per LOT 5 REPORT

6"PVC

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.011	
Channel Slope	0.005 ft/ft	(0.47 cfs = 82% of Q_{100} (0.57 cfs); 6" must only convey partial (+/- 50% Q_{100}) flow)
Normal Depth	6.0 in	
Diameter	6.0 in	
Discharge	0.47 cfs	

Results	
Discharge	0.47 cfs
Normal Depth	6.0 in
Flow Area	0.2 ft²
Wetted Perimeter	1.6 ft
Hydraulic Radius	1.5 in
Top Width	0.00 ft
Critical Depth	4.2 in
Percent Full	100.0 %
Critical Slope	0.007 ft/ft
Velocity	2.39 ft/s
Velocity Head	0.09 ft
Specific Energy	0.59 ft
Froude Number	(N/A)
Maximum Discharge	0.50 cfs
Discharge Full	0.47 cfs
Slope Full	0.005 ft/ft
Flow Type	Subcritical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	0.0 %
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	6.0 in
Critical Depth	4.2 in
Channel Slope	0.005 ft/ft
Critical Slope	0.007 ft/ft

8"PVC

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.011	
Channel Slope	0.005 ft/ft	(1.01 cfs > 100% of Q_{100} (0.57 cfs))
Normal Depth	8.0 in	
Diameter	8.0 in	
Discharge	1.01 cfs	

Results	
Discharge	1.01 cfs
Normal Depth	8.0 in
Flow Area	0.3 ft²
Wetted Perimeter	2.1 ft
Hydraulic Radius	2.0 in
Top Width	0.00 ft
Critical Depth	5.7 in
Percent Full	100.0 %
Critical Slope	0.007 ft/ft
Velocity	2.89 ft/s
Velocity Head	0.13 ft
Specific Energy	0.80 ft
Froude Number	(N/A)
Maximum Discharge	1.09 cfs
Discharge Full	1.01 cfs
Slope Full	0.005 ft/ft
Flow Type	Subcritical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	0.0 %
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	8.0 in
Critical Depth	5.7 in
Channel Slope	0.005 ft/ft
Critical Slope	0.007 ft/ft

Chase

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.013
Channel Slope	0.015 ft/ft
Bottom Width	1.00 ft
Discharge	2.10 cfs

Results	
Normal Depth	4.9 in
Flow Area	0.4 ft²
Wetted Perimeter	1.8 ft
Hydraulic Radius	2.7 in
Top Width	1.00 ft
Critical Depth	6.2 in
Critical Slope	0.008 ft/ft
Velocity	5.17 ft/s
Velocity Head	0.41 ft
Specific Energy	0.82 ft
Froude Number	1.429
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	4.9 in
Critical Depth	6.2 in
Channel Slope	0.015 ft/ft
Critical Slope	0.008 ft/ft

Design Procedure Form: Rain Garden (RG)

UD-BMP (Version 3.07, March 2018) **Sheet 1 of 2**

Designer:
Company: Farnsworth Group
Date: December 20, 2023
Project: APMI - Lone Tree
Location:

1. Basin Storage Volume	
A) Effective Imperviousness of Tributary Area, I_a (100% if all paved and roofed areas upstream of rain garden)	I_a = 57.0 %
B) Tributary Area's Imperviousness Ratio (i = I_a/100)	i = 0.570
C) Water Quality Capture Volume (WQCV) for a 12-hour Drain Time (WQCV= 0.8 * (0.91* i^3 - 1.19 * i^2 + 0.78 * i)	WQCV = 0.18 watershed inches
D) Contributing Watershed Area (including rain garden area)	Area = 34,027 sq ft
E) Water Quality Capture Volume (WQCV) Design Volume Vol = (WQCV / 12) * Area	V_{WQCV} = 514 cu ft
F) For Watersheds Outside of the Denver Region, Depth of Average Runoff Producing Storm	d_6 = in
G) For Watersheds Outside of the Denver Region, Water Quality Capture Volume (WQCV) Design Volume	$V_{WQCV\ OTHER}$ = cu ft
H) User Input of Water Quality Capture Volume (WQCV) Design Volume (Only if a different WQCV Design Volume is desired)	$V_{WQCV\ USER}$ = cu ft
2. Basin Geometry	
A) WQCV Depth (12-inch maximum)	D_{WQCV} = 6 in
B) Rain Garden Side Slopes (Z = 4 min., horiz. dist per unit vertical) (Use "0" if rain garden has vertical walls)	Z = 4.00 ft / ft
C) Mimimum Flat Surface Area	A_{Min} = 388 sq ft
D) Actual Flat Surface Area	A_{Actual} = 1442 sq ft
E) Area at Design Depth (Top Surface Area)	A_{Top} = 1918 sq ft
F) Rain Garden Total Volume (V_T= ((A_{Top} + A_{Actual}) / 2) * Depth)	V_T= 840 cu ft
3. Growing Media	Choose One: (•) 18" Rain Garden Growing Media ( ) Other (Explain):
4. Underdrain System	
A) Are underdrains provided?	Choose One: (•) YES ( ) NO
B) Underdrain system orifice diameter for 12 hour drain time	
i) Distance From Lowest Elevation of the Storage Volume to the Center of the Orifice	y = 2.9 ft
ii) Volume to Drain in 12 Hours	Vol_{12} = 514 cu ft
iii) Orifice Diameter, 3/8" Minimum	D_O = 1/2 in

Design Procedure Form: Rain Garden (RG)

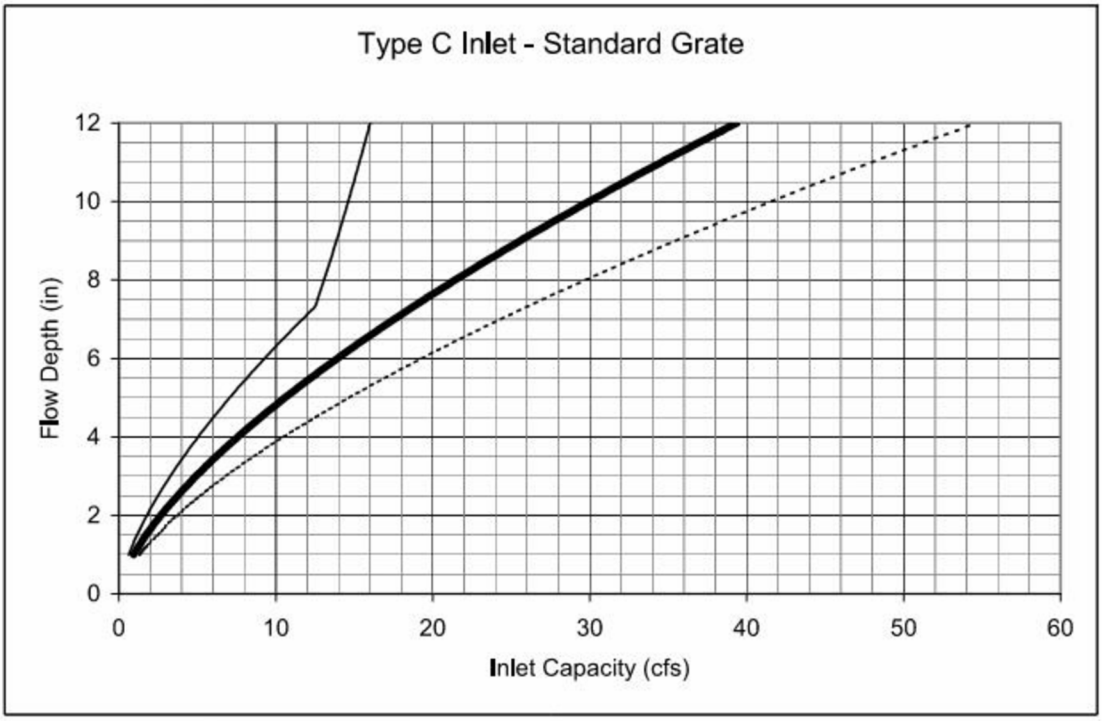
Designer:
Company: Farnsworth Group
Date: December 20, 2023
Project: APMI - Lone Tree
Location:

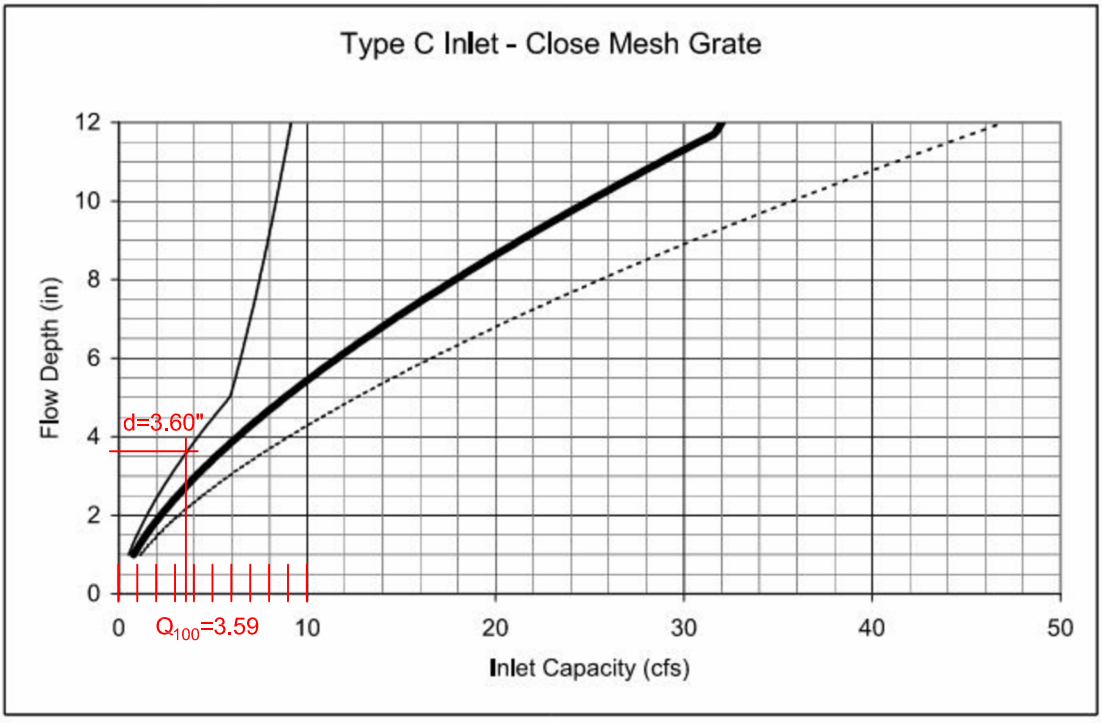
5. Impermeable Geomembrane Liner and Geotextile Separator Fabric A) Is an impermeable liner provided due to proximity of structures or groundwater contamination?	Choose One ○ YES ◉ NO
6. Inlet / Outlet Control A) Inlet Control	Choose One ○ Sheet Flow- No Energy Dissipation Required ◉ Concentrated Flow- Energy Dissipation Provided
7. Vegetation	Choose One ◉ Seed (Plan for frequent weed control) ○ Plantings ○ Sand Grown or Other High Infiltration Sod
8. Irrigation A) Will the rain garden be irrigated?	Choose One ○ YES ○ NO

Notes:

FIGURE 8-12, INLET CAPACITY CHART SUMP CONDITIONS

AREA (TYPE C) INLET





One Grate — Two Grates - - - - - - - - - Three Grates

Notes:

1. The Douglas County standard inlet parameters must apply to use these charts.

15"PVC

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.011	
Channel Slope	0.005 ft/ft	
Normal Depth	15.0 in	
Diameter	15.0 in	
Discharge	5.40 cfs	(5.40 cfs > Q_{100} (3.59 cfs))

Results	
Discharge	5.40 cfs
Normal Depth	15.0 in
Flow Area	1.2 ft²
Wetted Perimeter	3.9 ft
Hydraulic Radius	3.8 in
Top Width	0.00 ft
Critical Depth	11.3 in
Percent Full	100.0 %
Critical Slope	0.006 ft/ft
Velocity	4.40 ft/s
Velocity Head	0.30 ft
Specific Energy	1.55 ft
Froude Number	(N/A)
Maximum Discharge	5.81 cfs
Discharge Full	5.40 cfs
Slope Full	0.005 ft/ft
Flow Type	Undefined

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	0.0 %
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	15.0 in
Critical Depth	11.3 in
Channel Slope	0.005 ft/ft
Critical Slope	0.006 ft/ft

Farnsworth GROUP

Emergency Spillway

Job Name: APMI - Lone Tree

Date: 1/4/24

By: JMN

$Q = C_{BCW}LH^{1.5}$ (USDCM, Equation 12-8)

$Q = (2/5)C_{BCW}ZH^{2.5}$ (USDCM, Equation 12-9)

C_{BCW} = 3.00 (USDCM, Vol. 2, Chapter 12, Section 5.14.2)

Weir Inv. Elev. = 14.04

Q_{DESIGN} = 4.11 cfs

Elev.	H (ft)	L (ft)	Z (ft)	Q (cfs)
14.30	0.26	10.00		3.98
	0.26		4.00	0.17
	0.26		4.00	0.17
Total				4.31 cfs

Table 6-3. Recommended percentage imperviousness values

Land Use or Surface Characteristics	Percentage Imperviousness (%)
Business:	
Downtown Areas	95
Suburban Areas	75
Residential lots (lot area only)**:**	
Single-family	
2.5 acres or larger	12
0.75 – 2.5 acres	20
0.25 – 0.75 acres	30
0.25 acres or less	45
Apartments	75
Industrial:	
Light areas	80
Heavy areas	90
Parks, cemeteries	10
Playgrounds	25
Schools	55
Railroad yard areas	50
Undeveloped Areas:	
Historic flow analysis	2
Greenbelts, agricultural	2
Off-site flow analysis (when land use not defined)	45
Streets:	
Paved	100
Gravel (packed)	40
Drive and walks	90
Roofs	90
Lawns, sandy soil	2
Lawns, clayey soil	2

Table 6-4. Runoff coefficient equations based on NRCS soil group and storm return period

NRCS Soil Group		Storm Return Period					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
A	$C_A = 0.84i^{1.302}$	$C_A = 0.86i^{1.276}$	$C_A = 0.87i^{1.232}$	$C_A = 0.88i^{1.124}$	$C_A = 0.85i+0.025$	$C_A = 0.78i+0.110$	$C_A = 0.65i+0.254$
B	$C_B = 0.84i^{1.169}$	$C_B = 0.86i^{1.088}$	$C_B = 0.81i+0.057$	$C_B = 0.63i+0.249$	$C_B = 0.56i+0.328$	$C_B = 0.47i+0.426$	$C_B = 0.37i+0.536$
C/D	$C_{C/D} = 0.83i^{1.122}$	$C_{C/D} = 0.82i+0.035$	$C_{C/D} = 0.74i+0.132$	$C_{C/D} = 0.56i+0.319$	$C_{C/D} = 0.49i+0.393$	$C_{C/D} = 0.41i+0.484$	$C_{C/D} = 0.32i+0.588$

Where:

i = % imperviousness (expressed as a decimal)

C_A = Runoff coefficient for Natural Resources Conservation Service (NRCS) HSG A soils

C_B = Runoff coefficient for NRCS HSG B soils

$C_{C/D}$ = Runoff coefficient for NRCS HSG C and D soils.

Table 6-5. Runoff coefficients, *c*

Total or Effective % Impervious	NRCS Hydrologic Soil Group A						
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
2%	0.01	0.01	0.01	0.01	0.04	0.13	0.27
5%	0.02	0.02	0.02	0.03	0.07	0.15	0.29
10%	0.04	0.05	0.05	0.07	0.11	0.19	0.32
15%	0.07	0.08	0.08	0.1	0.15	0.23	0.35
20%	0.1	0.11	0.12	0.14	0.2	0.27	0.38
25%	0.14	0.15	0.16	0.19	0.24	0.3	0.42
30%	0.18	0.19	0.2	0.23	0.28	0.34	0.45
35%	0.21	0.23	0.24	0.27	0.32	0.38	0.48
40%	0.25	0.27	0.28	0.32	0.37	0.42	0.51
45%	0.3	0.31	0.33	0.36	0.41	0.46	0.54
50%	0.34	0.36	0.37	0.41	0.45	0.5	0.58
55%	0.39	0.4	0.42	0.45	0.49	0.54	0.61
60%	0.43	0.45	0.47	0.5	0.54	0.58	0.64
65%	0.48	0.5	0.51	0.54	0.58	0.62	0.67
70%	0.53	0.55	0.56	0.59	0.62	0.65	0.71
75%	0.58	0.6	0.61	0.64	0.66	0.69	0.74
80%	0.63	0.65	0.66	0.69	0.71	0.73	0.77
85%	0.68	0.7	0.71	0.74	0.75	0.77	0.8
90%	0.73	0.75	0.77	0.79	0.79	0.81	0.84
95%	0.79	0.81	0.82	0.83	0.84	0.85	0.87
100%	0.84	0.86	0.87	0.88	0.88	0.89	0.9
Total or Effective % Impervious	**NRCS Hydrologic Soil Group B**						
	2-Year	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**	**500-Year**
2%	0.01	0.01	0.07	0.26	0.34	0.44	0.54
5%	0.03	0.03	0.1	0.28	0.36	0.45	0.55
10%	0.06	0.07	0.14	0.31	0.38	0.47	0.57
15%	0.09	0.11	0.18	0.34	0.41	0.5	0.59
20%	0.13	0.15	0.22	0.38	0.44	0.52	0.61
25%	0.17	0.19	0.26	0.41	0.47	0.54	0.63
30%	0.2	0.23	0.3	0.44	0.49	0.57	0.65
35%	0.24	0.27	0.34	0.47	0.52	0.59	0.66
40%	0.29	0.32	0.38	0.5	0.55	0.61	0.68
45%	0.33	0.36	0.42	0.53	0.58	0.64	0.7
50%	0.37	0.4	0.46	0.56	0.61	0.66	0.72
55%	0.42	0.45	0.5	0.6	0.63	0.68	0.74
60%	0.46	0.49	0.54	0.63	0.66	0.71	0.76
65%	0.5	0.54	0.58	0.66	0.69	0.73	0.77
70%	0.55	0.58	0.62	0.69	0.72	0.75	0.79
75%	0.6	0.63	0.66	0.72	0.75	0.78	0.81
80%	0.64	0.67	0.7	0.75	0.77	0.8	0.83
85%	0.69	0.72	0.74	0.78	0.8	0.82	0.85
90%	0.74	0.76	0.78	0.81	0.83	0.84	0.87
95%	0.79	0.81	0.82	0.85	0.86	0.87	0.88
100%	0.84	0.86	0.86	0.88	0.89	0.89	0.9

Table 6-5. Runoff coefficients, *c* (continued)

Total or Effective % Impervious	NRCS Hydrologic Soil Group C						
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
2%	0.01	0.05	0.15	0.33	0.40	0.49	0.59
5%	0.03	0.08	0.17	0.35	0.42	0.5	0.6
10%	0.06	0.12	0.21	0.37	0.44	0.52	0.62
15%	0.1	0.16	0.24	0.4	0.47	0.55	0.64
20%	0.14	0.2	0.28	0.43	0.49	0.57	0.65
25%	0.18	0.24	0.32	0.46	0.52	0.59	0.67
30%	0.22	0.28	0.35	0.49	0.54	0.61	0.68
35%	0.26	0.32	0.39	0.51	0.57	0.63	0.7
40%	0.3	0.36	0.43	0.54	0.59	0.65	0.71
45%	0.34	0.4	0.46	0.57	0.62	0.67	0.73
50%	0.38	0.44	0.5	0.6	0.64	0.69	0.75
55%	0.43	0.48	0.54	0.63	0.66	0.71	0.76
60%	0.47	0.52	0.57	0.65	0.69	0.73	0.78
65%	0.51	0.56	0.61	0.68	0.71	0.75	0.79
70%	0.56	0.61	0.65	0.71	0.74	0.77	0.81
75%	0.6	0.65	0.68	0.74	0.76	0.79	0.82
80%	0.65	0.69	0.72	0.77	0.79	0.81	0.84
85%	0.7	0.73	0.76	0.79	0.81	0.83	0.86
90%	0.74	0.77	0.79	0.82	0.84	0.85	0.87
95%	0.79	0.81	0.83	0.85	0.86	0.87	0.89
100%	0.83	0.85	0.87	0.88	0.89	0.89	0.9

Table 6-2. NRCS Conveyance factors, K

Type of Land Surface	Conveyance Factor, K
Heavy meadow	2.5
Tillage/field	5
Short pasture and lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas and shallow paved swales	20

FIGURE 6-1
DOUGLAS COUNTY RAINFALL ZONES

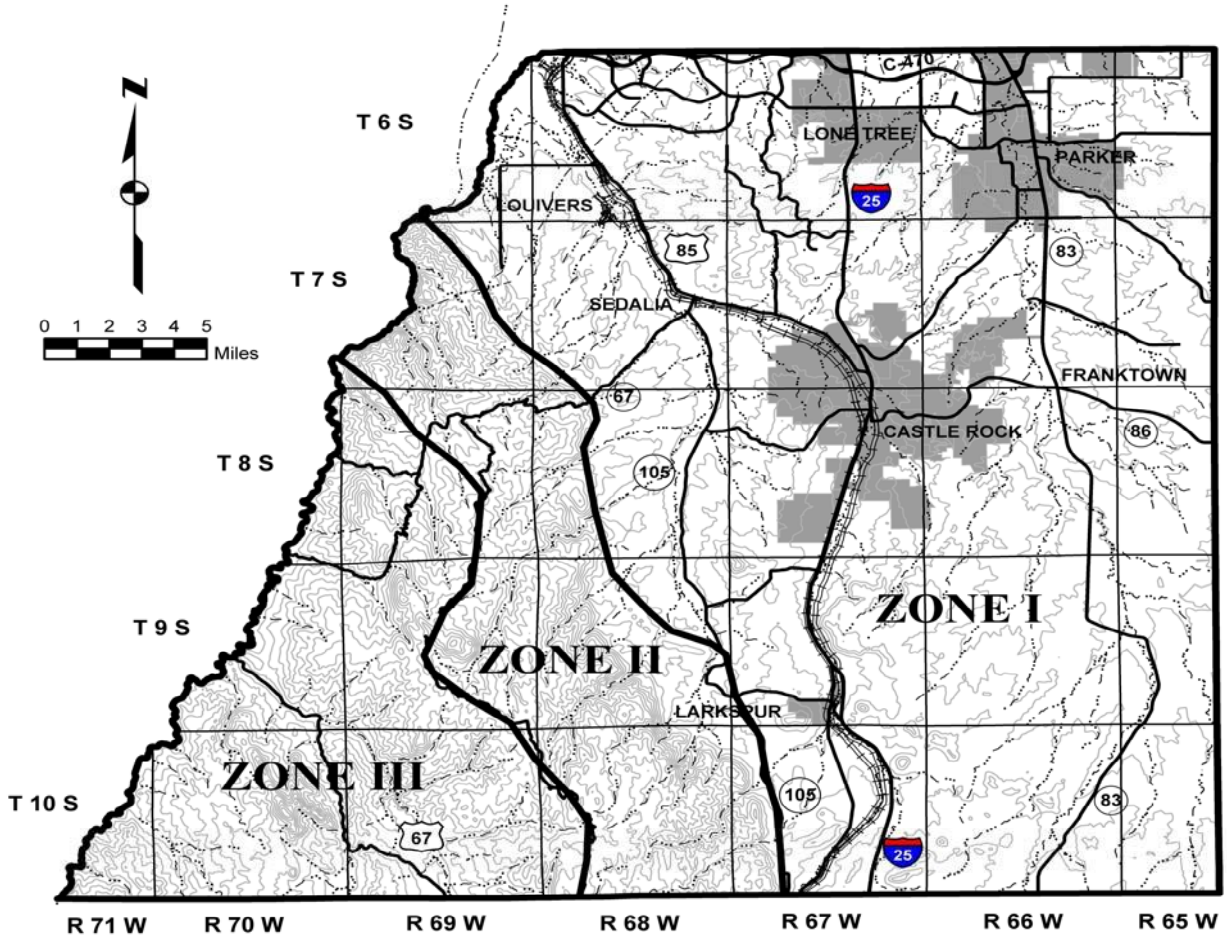
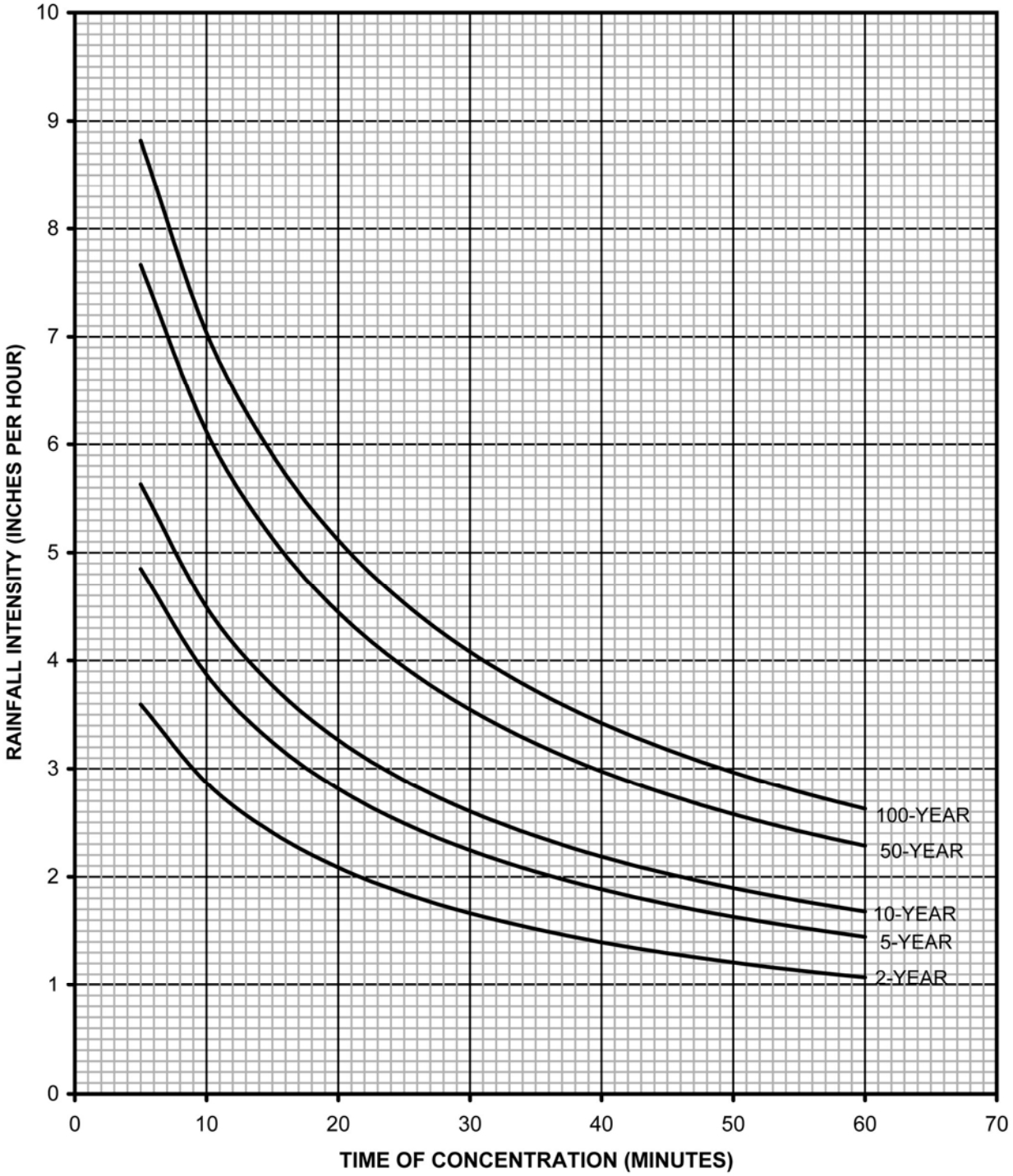
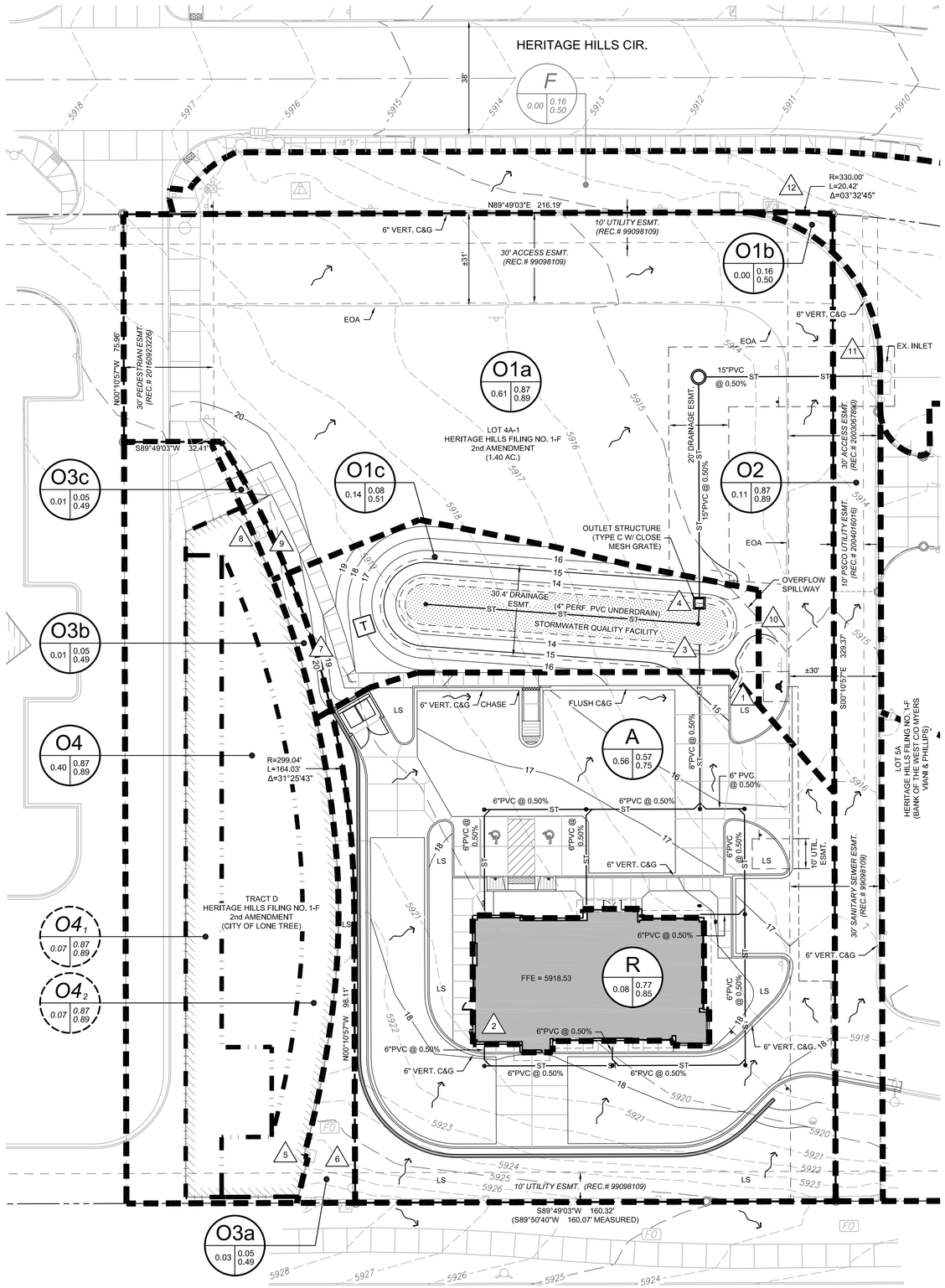


FIGURE 6-2
RAINFALL INTENSITY-DURATION CURVE
DOUGLAS COUNTY *ZONE I*





1 DRAINAGE MAP

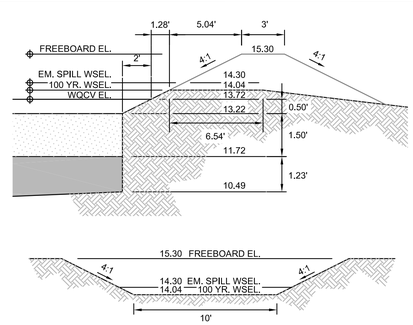
SCALE: 1" = 20'

0 10 20 40 U.S. SURVEY FEET

NORTH

LEGEND

- PROPERTY LINE
- ADJACENT LOT LINE
- RIGHT-OF-WAY LINE
- SECTION LINE
- CENTER LINE
- EXISTING EASEMENT
- PROPOSED EASEMENT
- EXISTING BUILDING/STRUCTURE
- EXISTING EDGE OF ASPHALT
- EXISTING CONCRETE
- EXISTING SIDEWALK
- EXISTING CURB & GUTTER
- CONCRETE PAVEMENT
- PROPOSED SIDEWALK
- PROPOSED CURB & GUTTER
- EXISTING FENCE
- SAWCUT LINE
- 5280 EXISTING MAJOR CONTOUR
- 5281 EXISTING MINOR CONTOUR
- 80 PROPOSED MAJOR CONTOUR
- 81 PROPOSED MINOR CONTOUR
- EOA EDGE OF ASPHALT
- C&G CURB AND GUTTER
- LS LANDSCAPE AREA
- ST EXISTING STORM SEWER
- ST PROPOSED STORM SEWER
- RD PROPOSED ROOF DRAIN
- PROPOSED MANHOLE
- EXISTING SIGN
- EXISTING SANITARY SEWER MANHOLE
- EXISTING STORM SEWER MANHOLE
- EXISTING DOWNSPOUT - SURFACE
- EXISTING INLET - CURB TYPE
- EXISTING WATER VALVE
- EXISTING FIRE HYDRANT
- EXISTING IRRIGATION CONTROL BOX
- E EXISTING ELECTRIC MANHOLE
- E EXISTING ELECTRIC PEDESTAL
- EXISTING ELECTRIC LIGHT - AREA / YARD
- EXISTING ELECTRIC LIGHT - STREET
- EXISTING ELECTRIC TRANSFORMER
- T EXISTING COMMUNICATIONS MANHOLE
- FO EXISTING FIBER OPTIC VAULT
- FO EXISTING FIBER OPTIC PEDESTAL
- PI 0.80 0.21 0.37 BASIN ID; C_5; C_{100}; AREA (AC.)
- PI 0.80 0.21 0.37 SUB-BASIN
- PI 0.80 0.21 0.37 EXISTING BASIN
- 6 DESIGN POINT
- FLOW DIRECTION
- PROPOSED SUB-BASIN LIMT
- PROPOSED BASIN LIMIT



4 OVERFLOW SPILLWAY

SCALE: NOT TO SCALE

FLOODPLAIN

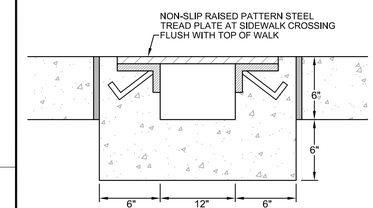
THE FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA), *FLOOD INSURANCE RATE MAP* (FIRM) *FOR DOUGLAS COUNTY, COLORADO AND INCORPORATED AREAS*, MAP NUMBER 08035C0042G, REVISED MARCH 16, 2016, INDICATES THE PROJECT SITE TO BE IN ZONE X (UNSHADED); "AREAS DETERMINED TO BE OUTSIDE THE 0.2% ANNUAL CHANCE FLOODPLAIN."

SUMMARY RUNOFF

DESIGN POINT	BASIN	AREA (AC.)	IMP. (%)	C_5	C_{100}	Q_5 (CFS)	Q_{100} (CFS)	REMARKS
	A	0.56	65	0.57	0.75	1.39	3.33	TO DP 1
2	R	0.08	90	0.77	0.85	0.29	0.57	TO DP 3
5	$O4_1$	0.07	95	0.87	0.89	0.30	0.55	TO DP 6
	O3a	0.03	2	0.05	0.49	0.01	0.14	TO DP 6
6						0.31	0.69	TO DP 1
1						1.34	3.20	
	(RUNOFF SPLIT AT D.P. 1)					(0.22)	(0.50)	TO DP 10
	(RUNOFF SPLIT AT D.P. 1)					(1.12)	(2.70)	TO DP 3
3						1.33	3.12	TO DP 4
7	O3b	0.01	2	0.05	0.49	0.00	0.03	TO DP 10
	O1c	0.14	6	0.08	0.51	0.06	0.65	TO DP 4
4						1.37	3.59	TO DP 11
10						1.59	4.11	TO DP 11
8	$O4_2$	0.07	95	0.87	0.89	0.31	0.58	TO DP 9
	O3c	0.01	2	0.05	0.49	0.00	0.02	TO DP 9
9						0.31	0.60	TO DP 11
	O1a	0.61	95	0.87	0.89	2.59	4.81	TO DP 11
	O2	0.11	95	0.87	0.89	0.47	0.86	TO DP 11
11						3.97	8.53	TO MS4
12	O1b	0.00	1.77	0.16	0.50	0.00	0.01	TO MS4
						3.97	8.54	TO MS4

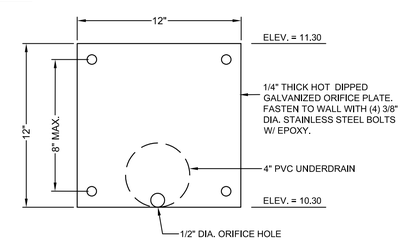
STORMWATER MANAGEMENT FACILITY

TRIBUTARY BASINS:	REQUIRED	DESIGN
TRIBUTARY BASINS:		A, R, O1c
TRIBUTARY AREA:		34,027 SF
TRIBUTARY IMPERVIOUSNESS:		57%
WQCV:	514 CF	840 CF
$WQCV_{AREA}$:	388 SF	1,442 SF
$WQCV_{DEPTH}$:	12 IN. MAX.	6 IN.



3 CHASE

SCALE: NOT TO SCALE



2 ORIFICE PLATE

SCALE: NOT TO SCALE

Farnsworth GROUP
5613 DTC PARKWAY, SUITE 1100
GREENWOOD VILLAGE, COLORADO 80111
(303) 692-8838 / info@f-w.com
www.f-w.com
Engineers | Architects | Surveyors | Scientists

ISSUE:

#	DATE:	DESCRIPTION:

PROJECT:

Chase Bank
Lone Tree, Colorado

9550 Heritage Hills Circle
Lone Tree, Colorado 80124

DATE:	03/04/2024
DESIGNED:	JMN
DRAWN:	JMN
REVIEWED:	JMN
FIELD BOOK NO.:	

SHEET TITLE:

DRAINAGE MAP

SHEET NUMBER:

1

PROJECT NO.: 0231559.00

J:\Revit | J:\2023\0231559.00 - 4PM Lone Tree\04_Drawings\DWG\CVX_Drainage Maps - 0231559.00.dwg | 3/4/2024 7:55 AM |