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RED DALE DRAINAGE BASIN DESIGN PLAN AMENDMENT

Project No. DR05-1452
CIP #50025

DOVER STREET DRAINAGE IMPROVEMENTS PROJECT

Prepared for:

City of Rapid City
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FEBRUARY 2010

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1.0 Introduction

The Red Dale Drainage Basin Design Plan Amendment (DBDPA) has been prepared by Ferber Engineering Company, Inc., for the City of Rapid City under Project No. DR05-1452 / CIP 50025 under the project title of the Dover Street Drainage Improvements. The DBDP has been prepared for the following reasons:

1) Update the original Red Dale Drainage Basin Design Plan to reflect revised hydraulic conditions,
2) Revise the Drainage Basin Design Plan to create a main outfall from the Drainage Basin along Cottonwood Street from Rapid Creek to Canyon Lake Drive, and
3) Update the original Red Dale Drainage Basin Design Plan to incorporate federally-mandated stormwater quality improvements.

In addition to this DBDPA, the following items have been included under Project No. DR05-1452:

1) Hartland Court Relocation Plans and Specifications
2) Water System Conversion Plan of the Soo San Low Level zone to the Canyon Lake High Level zone (Memorandum dated March 6, 2009)

The above reports, memorandums and plans have been provided to the City under separate cover.

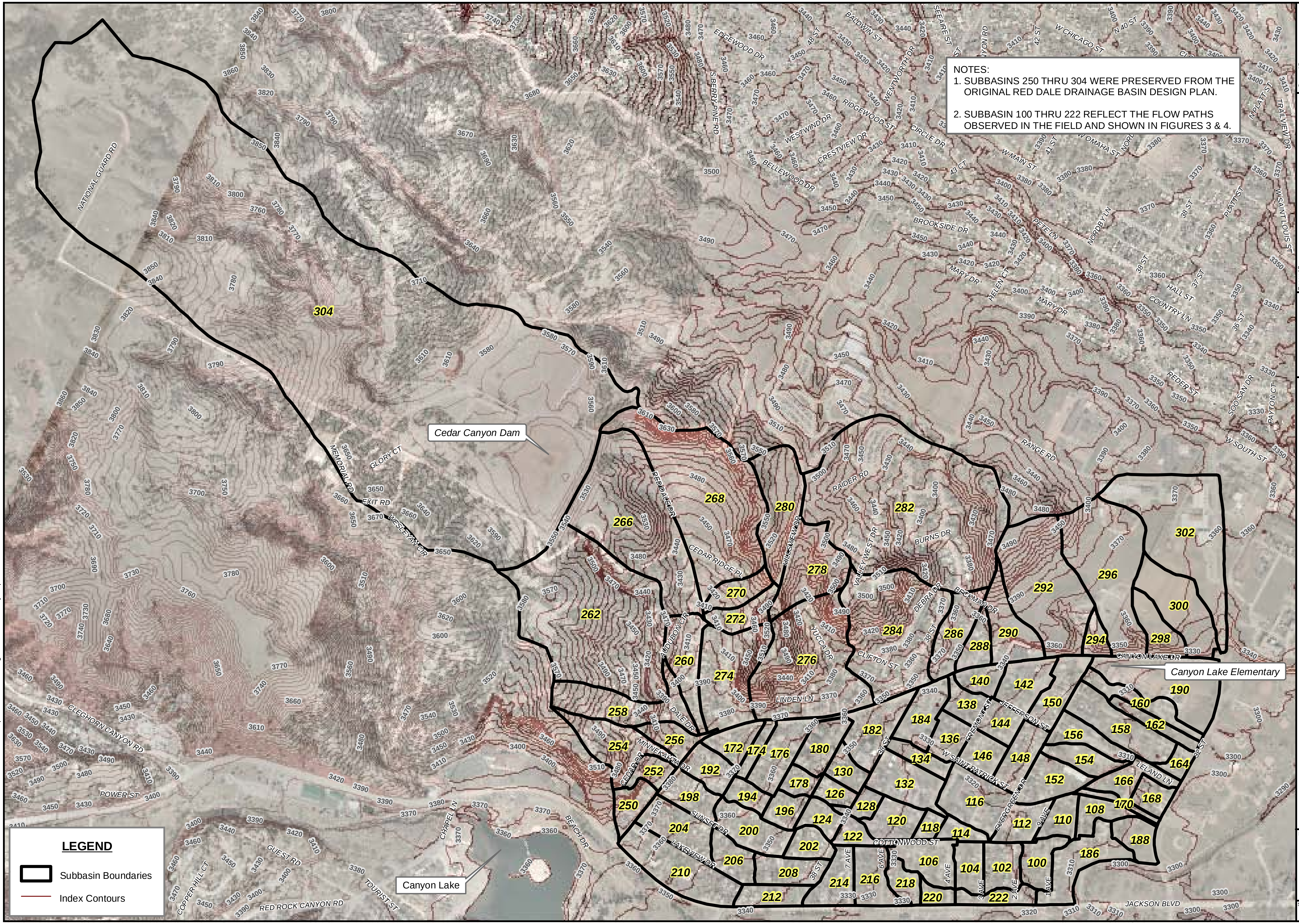
Phase 3 of the Dover Street Drainage Improvements project is slated to consist of the design and construction of the major downstream conveyance elements from Rapid Creek to Evergreen Drive. This DBDPA has been prepared to adequately determine the potential future contributing flow that will be conveyed to Rapid Creek. Figure 1 shows the Project Area.

1.1 Background

In the City of Rapid City Dover Street Drainage Improvements project, the City's intent is to reconstruct existing drainage facilities, construct new stormwater conveyance facilities and possibly construct stormwater quality treatment facilities within the Red Dale Drainage Basin, as prescribed in the Red Dale Drainage Basin Design Plan (DBDP). More specifically, this project involves drainage improvements and associated utility and street reconstruction in the Dover Street area of Rapid City.

Cedar Canyon Dam is a flood control reservoir that was constructed in Deadman Gulch (USGS name) in the late 1950's by the US Army Corps of Engineers. Its purpose is to provide flood control for the Canyon Lake neighborhood east of Canyon Lake Drive. Some of the subdivisions within this Canyon Lake neighborhood are: The Cottonwoods, several Schamber subdivisions, Sun Valley and Cedar Hills subdivisions. The western limits of the Red Dale Drainage are found on the National Guard reservation.

This DBDPA is needed to improve capacity and operation of storm drainage facilities in this neighborhood. Capacity of the existing drainage system is inadequate to convey stormwater flows without channel overtopping and localized flooding. Pools, stagnant water, excessive



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Sheet Title:
FIGURE 1.
GENERAL VICINITY MAP

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vegetation, slope failures, poor access and water quality problems all are thought to contribute to foul odors in the vicinity of drainage channels in the area. Additionally, the original Red Dale Drainage Basin Design Plan prescribed several large diameter storm sewer outfalls onto Meadowbrook Golf Course. In addition, in an effort to protect the beneficial use of the receiving water, Rapid Creek, the City desires to design and construct stormwater quality treatment facilities in conjunction with any recommended hydraulic stormwater facilities.

1.2 Objectives

This DBDPA is intended to be a guide for the City of Rapid City, other government agencies, landowners and concerned citizens within the limits of this Plan for use in the design and construction of major drainage facilities. Any improvements must safely, economically and aesthetically convey the major storm event to Rapid Creek while controlling in the shorter return period storms to the greatest extent practicable while limiting destruction of the natural drainage paths and ecosystems.

The objectives of the DBDPA include, but are not limited to:

1) Determine the 2-year, 10-year and 100-year storm discharges for each major drainage facility,
2) Determine the required facilities in Evergreen Drive and Cottonwood Street to collect and convey stormwater flows through one centralized outfall to Rapid Creek,
3) Identify and suggest improvements for existing regional and local drainage problems regardless of storm return period,
4) Prepare conceptual parameters for recommended regional drainage facilities,
5) Provide recommendations for stormwater quality improvements within the Plan area,
6) Provide updated conceptual engineer's opinions for probable construction cost for the recommended drainage improvements, and
7) Provide a prioritized list of recommended drainage facilities.

1.3 Design Plan Limitations

This DBDPA provides a conceptual outline of the major drainage improvements required to convey, and to an extent treat, the stormwater runoff generated within the Red Dale Drainage Basin to Rapid Creek. This DBDPA contains the necessary data to begin detailed design of specific drainage improvements. The improvements, when constructed, will form an efficient, planned stormwater management system to convey flows from the uppermost reaches of the Red Dale Drainage to Rapid Creek.

It is unlikely that all improvements will follow the outline of this Plan exactly. As facilities are constructed and modifications to the Plan are made, it is essential to adjust the computer models to accurately reflect the changes. In addition, a Design Plan Amendment document should be prepared and submitted to the City of Rapid City Public Works Department, Engineering Services Division. Any amendment documents and associated modeling information must be filed with this Plan for future public use. Users of this Plan are advised to contact the Rapid City Engineering Division to verify the accuracy of the design model and to ensure that the latest model version(s) are in use.

1.4 Report Organization

This DBDPA includes the following sections:

1.0 Introduction
2.0 General Subbasin Information
  2.1 Public Involvement
  2.2 Special Features and Problem Areas
3.0 Hydrologic Updates
  3.1 Labeling
  3.2 Subbasin Modifications
  3.3 Subbasin Hydrologic Summary
4.0 Hydraulic Updates
  4.1 Methodology
  4.2 Conveyance Elements
  4.3 Direct Flow / Diversion Elements
  4.4 Detention Elements
5.0 Cost Estimate
  5.1 Improvement Prioritization
6.0 Stormwater Quality
  6.1 Dover Street Channel
  6.2 Cottonwood Street Channel

Supporting information for the DBDPA has been provided in the following Appendices:

Appendix A – Subbasin Hydrographs / Subbasin Input
Appendix B –Design Plan and Existing Hydraulic Input Characteristics
Appendix C – Evergreen Drive (Element 8014) / Cottonwood Street (Elements 8002 and 8004) Conceptual Plan and Profile
Appendix D – Hartland Court Stormwater Quality Facility Conceptual Plan
Appendix E – 22”x34” DBDPA Exhibits
Appendix F – Digital Information

Unlike other Drainage Basin Design Plans, this document does not contain pages of model output. The new RCIDCM-stipulated modeling platform, HEC-HMS, does not provide a reporting engine. Therefore, both hydrologic and hydraulic input and output have been summarized in tables both within the text, where appropriate, and within the appendices.

The conceptual plans provided in Appendices C and D have been provided to present a clear scope of work required for the preliminary and final design of the recommended facilities for Phase III of the Dover Street Drainage Improvements. The profile/elevation data is provided within the conceptual plans to assist in the evaluation of the specific recommendations as the improvements relate to existing City utilities and Rapid Creek.

1.5 Deliverables

A digital video disk (DVD) will be provided in Appendix F with the Final submittal of this report. The DVD will contain:

- HEC-HMS Existing and DBDP Models
- ESRI Geodatabase
- Other Digital Support Information
- PDF versions of the various conceptual plans

1.6 Support Literature

The following literature and data was used in the development of this Plan. The list of information provided may not be all inclusive of the information used. The background data has been segregated according to the following categories:

- Technical References
- Planning Studies
- Technical Documentation
- Other Data

1.6.1 Technical References

Rapid City Infrastructure Design Criteria Manual (DRAFT), (RCIDCM), City of Rapid City, 2008.

Rapid City Stormwater Quality Manual, (RCSQM) City of Rapid City, 2009.

Rapid City Drainage Criteria Manual, (RCDCM), City of Rapid City, 1989.

Urban Storm Drainage Criteria Manual, (USDCM), Urban Drainage and Flood Control District, Denver, CO, current edition.

Open Channel Hydraulics, Ven Te Chow, 1959.

Stormwater Collection Systems Design Handbook, Larry W. Mays, 2001.

Handbook of Hydraulics, 6th ed., Brater and King, 1982.

Hydrologic Modeling System HEC-HMS User's Manual (CPD-74A), United States Army Corps of Engineers Hydrologic Engineering Center.

Hydrologic Modeling System HEC-HMS Technical Reference Manual (CPD-74B), United States Army Corps of Engineers Hydrologic Engineering Center.

Hydraulic Design of Flood Control Channels, EM 1110-2-1601, United States Army Corps of Engineers and American Society of Civil Engineers, 1995.

1.6.2 Planning Studies

Red Dale Drainage Basin Design Study, Alliance of Architects and Engineers, 1992. *Evergreen Apartments Drainage Report*, Britton Engineering and Land Surveying, Inc., 2006.

Phase 1 Hartland Court Relocation Preliminary Design Report, Ferber Engineering Company, Inc., 2009.

Rapid City Major Drainage Facilities Overview Report, City Project ST07-1614, FourFront Design, Inc., 2007.

Utility System Master Plan, Burns and McDonnell, Inc., 2008.

Comprehensive Road Condition Report, City of Rapid City, 2008.

1.6.3 Construction / Record Plans

Jackson Boulevard Reconstruction Plans (Preliminary), Project P 0044(00)40, South Dakota Department of Transportation, October 2008.

Canyon Lake Drive Utility Relocations, Project W78-2, City of Rapid City, 1978.

West St. Patrick Street 48" Storm Sewer, City of Rapid City, 1978. *Schamber Addition, (Cleghorn Water Association) Water Main Extension*, City Project No. W03-1286, Ferber Engineering Company, Inc., 2005.

Evergreen Water Main Reconstruction, City Project No. W07-1645, City of Rapid City, 2007

Hartland Court and Empey Drive Sanitary Sewer Reconstruction, City Project No. SS00-887, City of Rapid City, 2000.

Cedar Canyon Flood Control Channel, Storm Sewer District 25, City of Rapid City, date unknown.

32nd Street Street and Utility Reconstruction, City Projects ST90-338 and SSW90-6, City of Rapid City, 1990.

Red Dale Drainage Phase 1, City Project D79-5, City of Rapid City, 1979.

Red Dale Drainage Phase II, City Project D80-1, City of Rapid City, 1980.

Simpson Drive Sewer and Water, City Project D20-B.

Meadowbrook Golf Course Utility Reconstruction, City Project D20-D.

Monte Vista Drive Water and Sewer, City Project D20-D.

St. Patrick Street Sanitary Sewer, City Project D20-D.

Red Dale Drainage 42" Arch Concrete Pipe, City Project DR98-725.

Jackson Boulevard and 32nd Street, City Project F0044-42.

Heartland Court and Empey Drive Sanitary Sewer Reconstruction and Water Construction, City Project S6591(2).

Jackson Boulevard Sanitary Sewer Reconstruction and Water Construction, City Project PR01-102.

Canyon Lake Drive, City Project M1746(5).

Canyon Lake Drive, City Project M1746(1) and TQM 1746(1).

Jackson Boulevard, City Project S6591(2).

Canyon Lake Drive Utility Relocation, City Project W78-2.

Dale Drive Water Main Construction, City Project W99-900.

1.6.4 Digital Data Obtained for Study

Water and Sanitary Sewer Geodatabases, current version

City Street Centerline Shapefiles

City Parcel Boundaries

2008 Color Aerial Orthophotography and 2-foot Aerial Topography

2007 Major Drainage Overview Geodatabase

2.0 Basin Information

The Red Dale Drainage Basin encompasses a total of 858 acres that includes undeveloped forest west and north of Canyon Lake Drive and residential and commercial development along and south of Canyon Lake Drive. There are six general outfall locations within the drainage. The outfall contributing basins are shown on Figure 2 and are defined as:

- 32nd Street (265 ac)
- Cedar Canyon Dam (272 ac)
- Canyon Lake Elementary (95 ac)
- Hartland Court (17 ac)
- Jackson Boulevard (65 ac)
- Park Drive (144 ac)

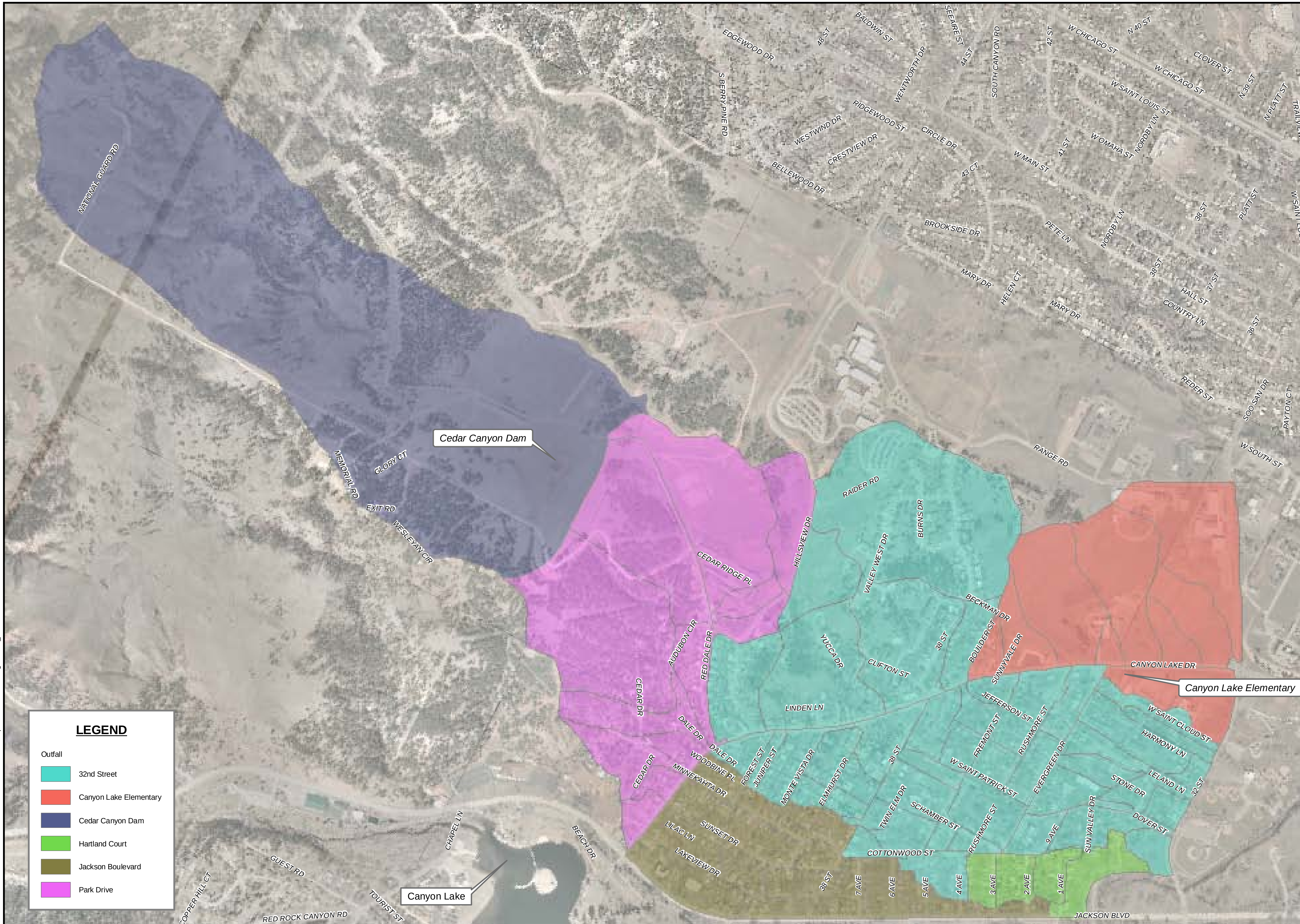
The areas provided represent the contributing area to these general locations based on existing flow patterns. The DBDPA recommendations substantially change the outfall configurations. The results of the DBDPA outfall reconfigurations are shown in Figure 3 and discussed in Section 4.0 of this amendment.

This section of the DBDPA presents some of the typical DBDP information regarding the characteristics of the drainage basin as well as some new items, such as public involvement. Since this is an amendment to an existing plan, the general discussions of topography, soils and other items are not provided. Where necessary these items are discussed briefly in the Hydrologic Updates section of this study to describe the differences between the original analysis and this analysis.

2.0.1 Future Land Use

No Future Land Use Plan has been prepared for this study area. The Red Dale Drainage Basin for all practical purposes is fully-developed. The Canyon Lake Drive immediate corridor land use is primarily commercial with interwoven residential areas. The land use north and west of Canyon Lake Drive is a mixture of undeveloped public ground owned by South Dakota National Guard and Rapid City School District with narrow corridors of low density residential occurring along the street rights-of-way. South and east of Canyon Lake Drive a combination of low density residential (LDR) and medium density residential (MDR) predominate the land uses. Some of the MDR existed at the time of original plan development, but most has occurred in the last 10 to 15 years and may or may not be reflected in the CUHP modeling.

The original DBDP future land use designations were reviewed in relationship to existing uses. Other than a few isolated areas of medium density residential (MDR) that have developed along Fremont Street, Evergreen Drive and 38th Street, the general concept of the original land use assumptions remains intact. Therefore, no modifications to the fully-developed land use conditions were made in this study.



DATE: 7/30/2009 FILE: \\Fe-server\PROJECTS\09-101\GIS\ReportExhibits\11x17 Figure 2 Ex_Subbasin Outfall Location.mxd

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Sheet Title: FIGURE 2. EXISTING DRAINAGE OUTFALL

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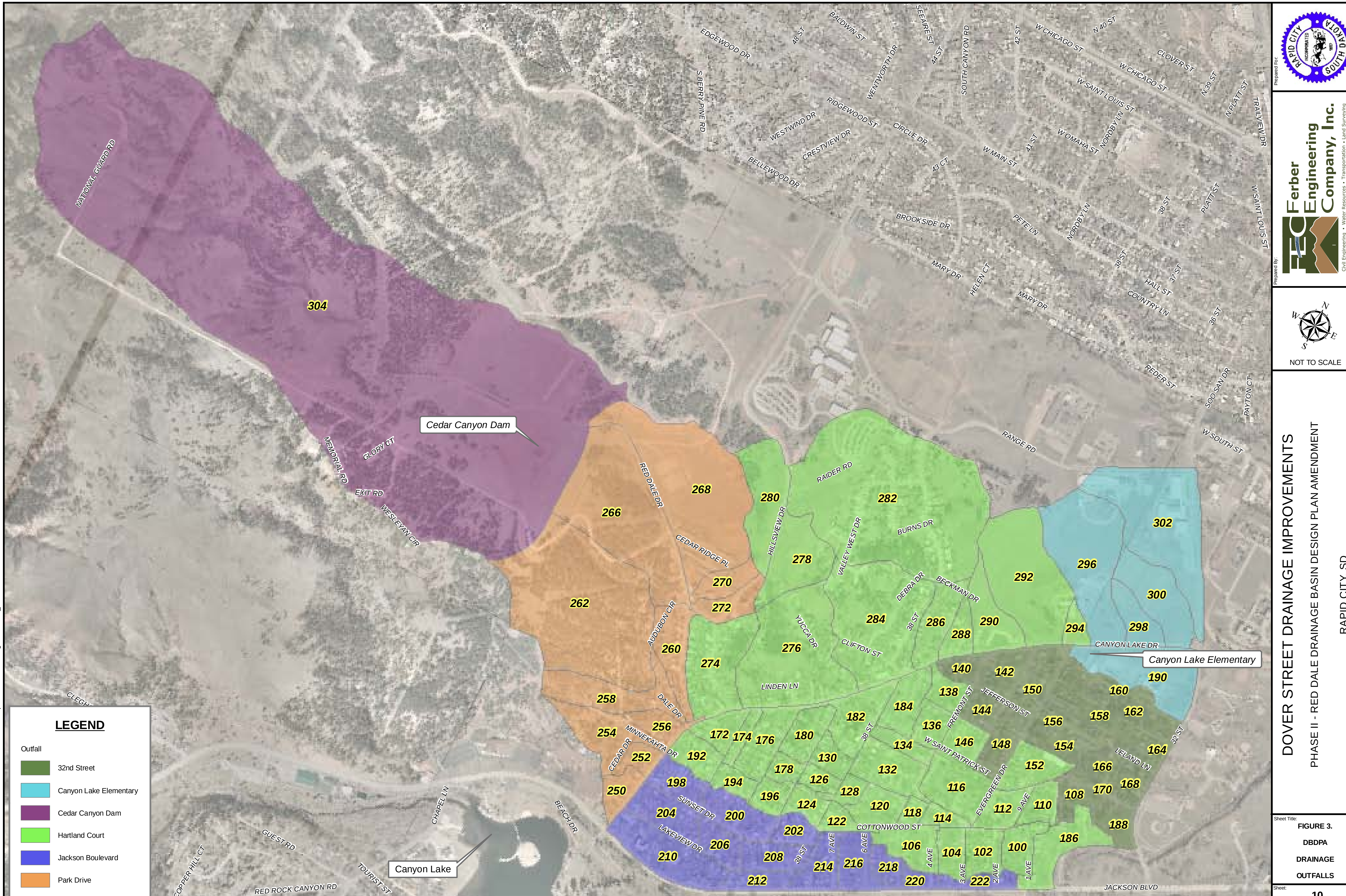

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2.0.2 Street Classification

The current Major Street Plan was reviewed to determine the City's classification of the various transportation corridors within the study area. The classifications are important as they dictate what stormwater inundation level is allowed under current design criteria. In general, all streets are classified as local streets with the exception of the following:

- 32^{nd} Street and Raider Road are classified as Collector Streets
- Hillsview Drive and Red Dale Drive are classified as Minor Arterial Streets
- Canyon Lake Drive is classified as a Minor Arterial Street
- Jackson Boulevard is classified as a Principal Arterial Street

The design criteria used in this study is different than that used in the original study. The RCIDCM stipulates the revised street flow criteria in Table 4-6 for the allowable 10-year runoff encroachment, Table 4-9 for the allowable 100-year runoff inundation and Table 4-10 provides allowable cross street flow depths. For purposes of this study, available capacity (depth), either controlled by depth criterion or actual topographic depth, whichever is less, was used in determining allowable street flow, approximate storm inlet needs, as well as approximate storm sewer sizing.

2.0.3 Wetlands

A cursory review of the United States Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps shows only minor palustrine environments existing within the study area outside of Rapid Creek. Because of the dissected nature of the drainage network and because all but one short section of native channel has been substantially manipulated, it is unlikely that the recommended improvements other than at Rapid Creek will require permit coverage under Section 404 of the Clean Water Act as regulated by the United States Army Corps of Engineers. Improvements at Rapid Creek will require Section 404 permit coverage.

2.0.4 Floodplain

Regulatory floodplain exists within the study area and is directly related to Rapid Creek. The floodplain affecting the area can be found in the Flood Insurance Rate Map (FIRM) Panels 465420 0003F, 465420 0004F and 465420 0011F. These three FIRM panels have effective dates of February 16, 1996. In general, the north boundary of the Rapid Creek floodplain is Jackson Boulevard from Hartland Court to Canyon Lake Drive.

East of Hartland Court, Rapid Creek crosses Jackson Boulevard from south to north and then turns back to the east and crosses 32^{nd} Street a few hundred feet north of Jackson Boulevard. Along this reach, the floodplain is located almost entirely within the City parkland until it reaches the Hartland Court cul-de-sac. At that point the west/north boundary of the 100-year floodplain is east of Ryther Street and extends generally to Leland Lane.

The Red Dale Drainage Basin outfall improvements recommended in this plan along Cottonwood Street will require flood analysis and completion of a floodplain development permit. The proposed facilities have been developed with the potential flood impacts in mind. It was beyond the scope of this study to complete a detailed hydraulic analysis of the potential impacts to the Rapid Creek floodplain.

2.1 Public Involvement

In late April 2009, questionnaires were sent out to the owners of approximately 742 properties within the Canyon Lake Drive to 32nd Street portion of the study area. The questionnaires were used as a way to empower the neighborhood in the development of this plan. The questions asked of the residents/owners included specifics regarding the generalized items below:

- Sanitary sewer service connections
- Water service connections
- Existence of Sump Pumps
- Local Drainage Issues

Of the 742 properties within the study area, 384 responses were received for a response rate of approximately 52%. Figure 4 shows the coverage of the responses and the generalized land use of each of the respondent properties.

In general, a majority of the residents appear not to be aware of whether or not their water/sanitary services are common or not. Of the returned questionnaires, there are 22 known common sanitary sewer service lines and 99 “don’t knows”. The sanitary sewer service cards *were not* reviewed for the study area, but it is likely that the 6% of known common sanitary service lines can be carried to the 742 properties for at least 45 common sanitary services east and south of Canyon Lake Drive. According to the results, there are seven (7) known common water service lines with 91 responses of “don’t know”.

There are 69 known sump pumps within the properties of the returned questionnaires. Of those 69, seven (7) are knowingly hooked to the sanitary sewer, thirteen do no know and the remainder of the properties with sump pumps drain directly to the storm sewer (11) or to the yard.

The main use of the questionnaire answers was to determine the extent of local drainage issues so that these issues can be addressed within this DBDPA. A significant number of comments were received on local issues as well as descriptions of problems blocks away from the address of the respondent. Many of the comments regarded the odor and stagnant water in three primary locations: the private pond near the intersection of Dover Street and Evergreen Drive, the Dover Street channel and the detention facility located at Canyon Lake Elementary School. Additional comments were received about “raging” rivers on Dover Street and Yucca Street.

One area of significant concern presented not only in the questionnaires, but through telephone calls was the drainage and drainage facilities associated with the Evergreen Apartments located between Harmony Lane and Leland Lane. Other more minor issues such as sediment deposition, failing curb and gutter, etc, were presented by various respondents.

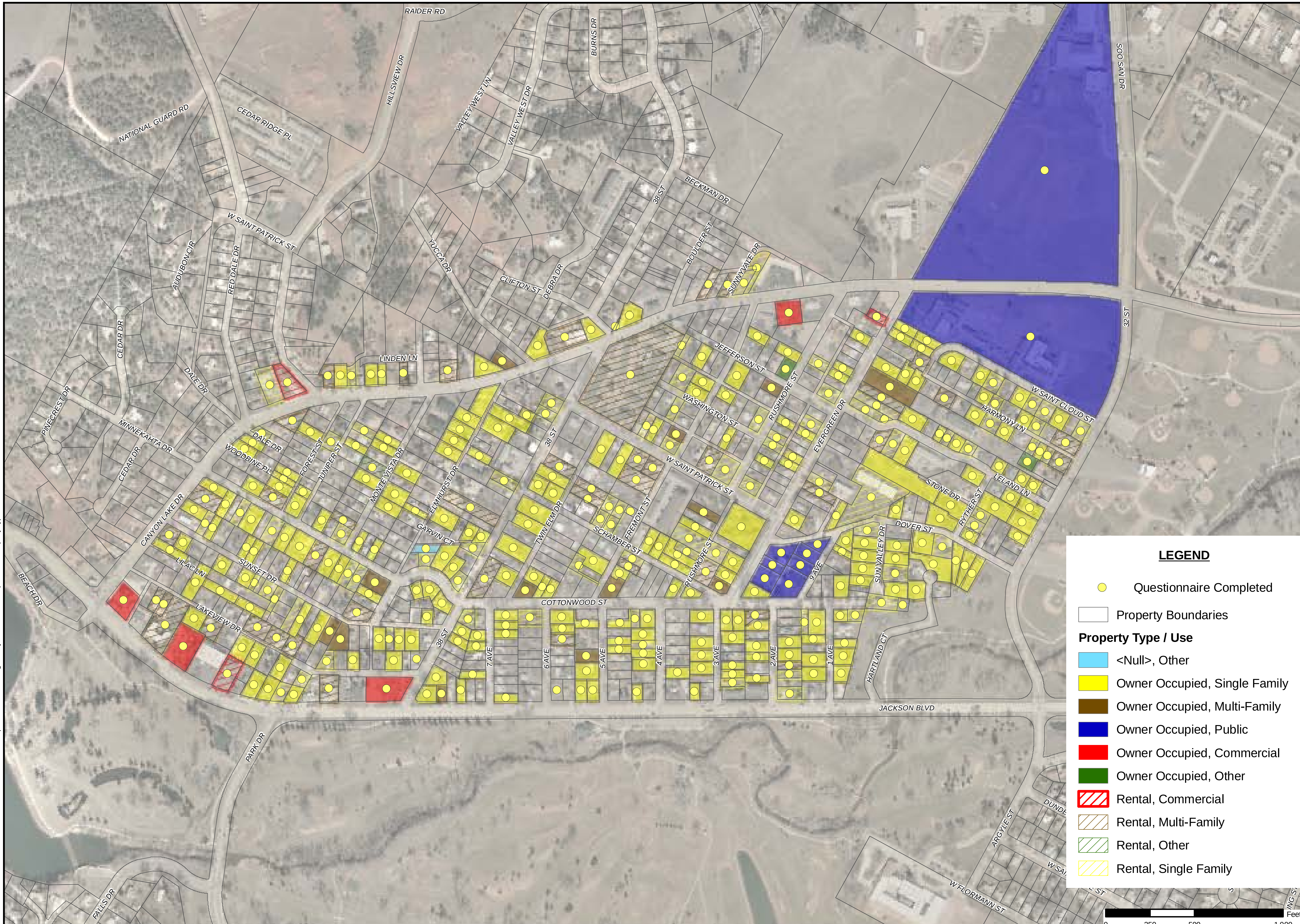

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FIGURE 4. PROPERTY TYPE AND QUESTIONNAIRES

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To simplify demonstration of the drainage-related issues, responses were categorized by "Surface Water" or "Groundwater". Of the 384 responses, 132 responses (34%) specifically addressed drainage issues. Figure 5 shows the categorization. Other than in only a few instances, the groundwater issues seem to be directly related to either the Canyon Lake School detention facility or the Evergreen Drive facility.

2.2 Special Features and Problem Areas

This drainage basin has a number of features that received attention during the development of this plan. The following brief descriptions of the specific areas are presented to demonstrate existing issues that have to an extent been presented above.

2.2.1 Dover Street Channel

This channel currently is the primary outfall of a majority of the developed portion of the Red Dale Basin. It extends from Leland Lane along rear property lines to Evergreen Drive. It is directly adjacent to the north side of Dover Street from Sun Valley Drive to Evergreen Drive. It currently receives stormwater runoff from approximately 265 acres.

The existing channel is an earthen trapezoidal channel with approximate 2H:1V side slopes and a 3-foot wide bottom along its length. Between Sun Valley Drive and Evergreen Drive, the channel is crossed by three driveways each with substantially undersized culverts. The channel appears to be correcting itself to high velocities by downcutting and creating an incised main channel. The incising of the channel is also creating pools, which allows water to become stagnant and provides a breeding ground for mosquitoes. The channel is substantially smaller than that required to pass the existing flows. Picture 1 shows the channel along Dover Street.

Picture 1. Dover Street Channel along Dover Street

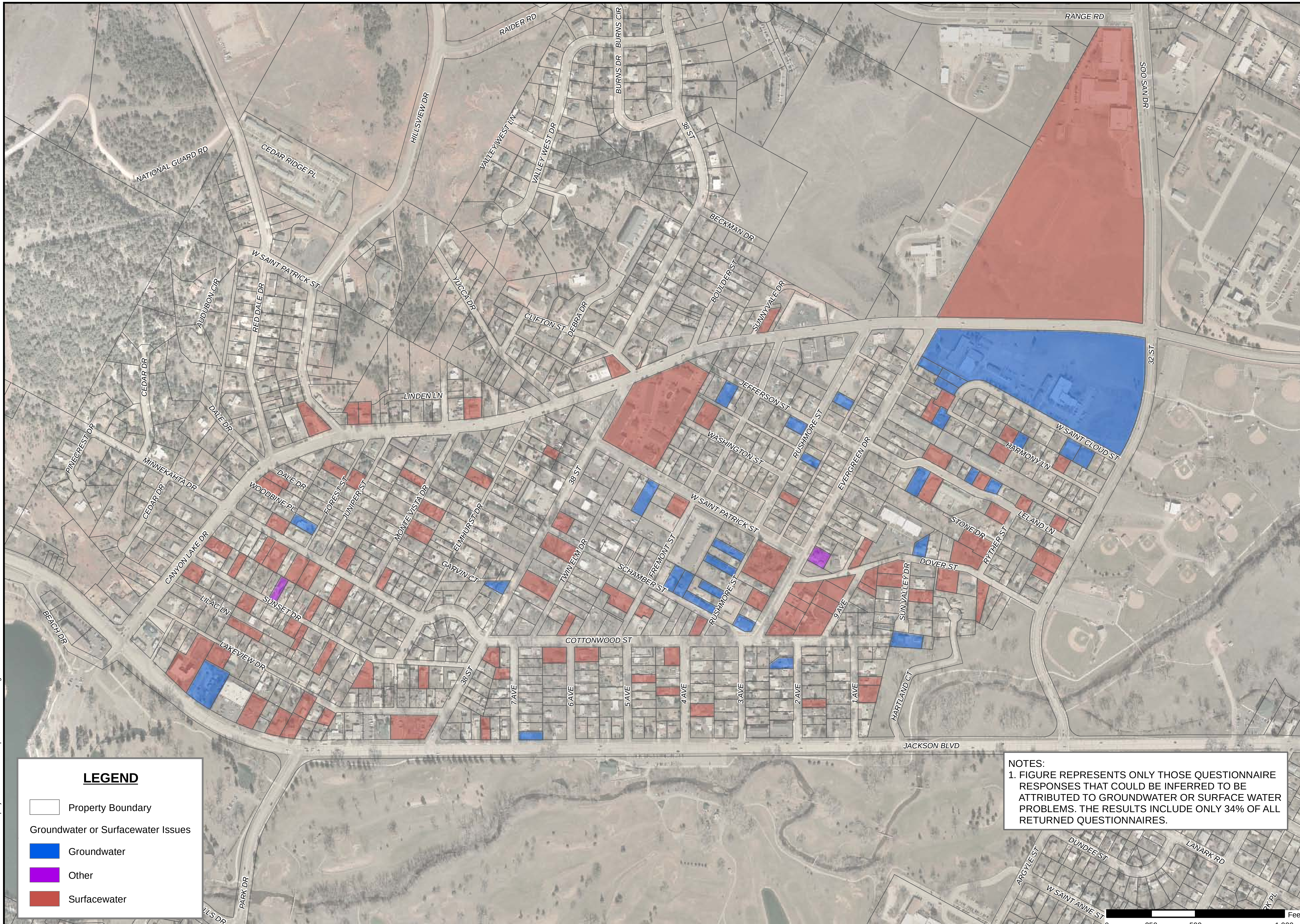

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FIGURE 5. GROUNDWATER & SURFACEWATER ISSUES

Sheet:

15

The extent of channel from Leland Lane to Sun Valley Drive has similar geometric characteristics to that described above. However, the channel is badly overgrown. Some of the maintenance issues are directly related to the fact that the channel is located within a 15-foot drainage easement. The crest-to-crest dimension of the channel consumes this 15-foot easement making maintenance access difficult, if not impossible. There is also one culvert crossing in this reach of channel. Picture 2 shows this reach of the Dover Street channel.

Picture 2. Dover Street Channel south of Leland Lane

2.2.2 Evergreen Drive Pond

Picture 3 shows the private pond west of Evergreen Drive, which is referred to herein as Evergreen Drive Pond. This pond is a remnant of historic irrigation channel and a portion of the Cedar Canyon Flood Control Channel. The retention pond is located on the existing main outfall channel immediately upstream of the Dover Street Channel. The two facilities are connected by three 42-inch diameter pipes under Evergreen Drive.

The existing facility is located on private property. No easement exists for this facility. As mentioned in many of the questionnaires as well as by the City at the beginning of this project, odor from the facility is a major nuisance. The odor is produced from a naturally occurring process called eutrophication, which in this case, is probably intensified by lawn fertilizer and other organic compounds. There is little circulation of the water "stored" within this facility. Based on review of the questionnaires and the stated groundwater problems in the immediate area (Figure 5), it appears that this pond may be contributing to the high groundwater.

Picture 3. Evergreen Drive Pond

The City has had conversations with the landowner about acquisition of the pond or at least an easement to assist with maintenance. To this point, the landowner has been unwilling to grant an easement. No subsequent contact was made during the development of this plan. Since the flow currently contributing to this facility will be substantially reduced by the DBDPA recommended elements, it may be possible to divert W. St. Patrick Street storm sewer flows down Rushmore Street in sufficient quantity to provide circulation and thereby reducing the effects of the eutrophication process. This is discussed in more detail within the Hydraulics Updates section of the study. Without some type of access agreement it will be difficult to provide any other type of improvement to this facility than the diversion of storm sewer flows.

Picture 4 presents the influent channel to Evergreen Drive Pond. As shown, this channel is substantially overgrown and appears to contribute to potential mosquito problems in the area. There is no easement for this channel, but it may be possible to acquire one in order to improve both the function and aesthetics of this channel. This plan proposes that an easement should be pursued and improvements to the channel be completed.

Picture 4. Channel Upstream of Evergreen Drive Pond

2.2.3 Canyon Lake Drive

All of the Canyon Lake Drive side street intersections west of and including 38th Street are not in compliance with current street criteria. These side streets do not provide an approach length of 50 feet with a grade less than or equal to five percent (5%). As a result, it was difficult to correctly construct the pans to keep runoff in Canyon Lake Drive. Runoff from even the smaller rainfall events is directed down the local streets adding to the local drainage problems experienced without the diversions. Correcting the vertical profiles of the side streets will help, but the profiles will still not comply with criteria simply due to the existence of homes and business directly adjacent to the side streets.

Many of the Canyon Lake Drive overflow to side street issues are a direct result of the lack of adequate storm inlets and storm sewer capacity to meet current criteria. An existing 48-inch/54-inch storm sewer in Canyon Lake Drive is dedicated to the outflow from Cedar Canyon Dam and Red Dale draw, so very few inlets are found along Canyon Lake Drive from Hillsview Drive to Jackson Boulevard.

Canyon Lake Drive is currently on the 2009-2014 Capital Improvements Program (CIP) for 2010 construction. Many of the DBDPA recommendations can be constructed during this project.

2.2.4 Canyon Lake Elementary Detention

This is an existing detention cell located in the southeast corner of the school property. Its outfall is located approximately 300 feet south of the intersection of Canyon Lake Drive and 32nd Street. The outlet from the facility consists of three 18-inch pipes that discharge to the east of 32nd Street, where flows are conveyed to Rapid Creek via open channels.

Based on review of the questionnaires and the stated groundwater problems in the immediate area (Figure 5), it appears that this pond may be contributing to the high groundwater.

2.2.5 Hartland Court

Phase 1 of the Dover Street Drainage Improvements project deals with the redesign of Hartland Court to move the intersection from Jackson Boulevard to a new intersection on 32nd Street. The purpose of the project is to improve intersection safety, but also to create room for a stormwater quality treatment facility associated with this study. The Hartland Court Relocation project also provides enhancements to the City greenway.

The proposed DBDPA outfall location will be created at the east terminus of Cottonwood Street. The construction of proposed outfall facilities will incorporate parkland enhancements while treating stormwater prior to discharging to Rapid Creek.

3.0 Hydrologic Updates

This DBDPA was completed using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS), which is the new modeling platform prescribed in the RCIDCM. HEC-HMS replaces the former Colorado Unit Hydrograph Procedure (CUHP) used for hydrologic modeling and the Urban Drainage Stormwater Management Model (UDSWMM), which were utilized in the development of the original DBDPs.

Originally, it was anticipated that that portion of the study area contained by Canyon Lake Drive, 32nd Street and Jackson Boulevard would be the only area where a complete hydrologic remodeling task would be completed. The idea was that the CUHP hydrographs for the subbasins outside of Canyon Lake Drive would be input using the Time-Series Discharge Gage paired data set module. However, initial runs of the 10-year and 100-year CUHP models did not verify the published model results.

The original models were run in CUHPD. The current version is CUHP2000. Several iterations of the internal modeling algorithms have taken place since the D version of the program. The model input files were also tried in CUHPE version of the software; however, CUHPE and older versions are DOS driven programs which no longer function properly within the Windows operating system. Rather than spending a significant amount of time resolving the issue, the model was converted to HEC-HMS, which is the ultimate goal of the City for all existing design plans.

The following sections discuss the hydrologic and hydraulic changes associated with this study.

3.1 Labeling

The process of developing a drainage basin design plan includes the computer simulation of runoff from each of the subbasins. Subbasin flows are then routed through a network of conveyance elements. This section is included to provide information regarding specific changes to the hydrologic modeling of the Red Dale Drainage Basin.

The hydrologic and hydraulic element identification convention changed in this amendment to the following:

- 100 – 304 Subbasin Labels

Existing Conditions Labels

- 1 – 149 Existing Conveyance Elements
- 300 – 302 Existing Detention Elements
- 1000 – 6000 Existing Direct Flow / Diversion Elements

Design Plan Amendment Labels

- 7000 – 7050 DBDPA Direct Flow / Diversion Elements
- 8000 – 8050 DBDPA Conveyance Elements

3.2 Subbasin Modifications

The subbasins south and east of Canyon Lake Drive were redelineated to account for land use changes made following completion of the original plan. The City's 2008 digital aerial topography, which has better resolution than that used in the original plan development, was used for basin delineations. Additionally, the new subbasins were developed to define areas of documented drainage issues; the modifications were based on flowpaths observed during snowmelt in April 2009 and heavy rainfall in May and June of 2009. Figures 6 and 7 show the field verified flowpaths. Only major boundary revisions were completed for Subbasins 100 through 222, which are all located south and east of Canyon Lake Drive. Only very minor revisions were made to Subbasins 250 through 304, which are all located north and west of Canyon Lake Drive.

3.2.1 Impervious Area

The mapped impervious area (MIA), which is the impervious area that can be defined by use of aerial photography and other methods, was determined for Subbasins 100 through 222. Mapped impervious area represents the total surface within a subbasin that produces a nearly 1:1 ratio of rainfall to runoff. Using the 2008 color orthophotography in the Geographic Information System (GIS), the MIA was delineated in three different residential areas over one square block each east and south of Canyon Lake Drive. The average MIA over these three residential blocks was 42.12%. Commercial area imperviousness was measured from the orthophotography within each subbasin. Area weighted impervious percentages were calculated based on the areas of residential, commercial and pervious surface within each subbasin. The original DBDP impervious percentage values were used in Subbasins 250 through 304 as a cursory review showed that the imperviousness used represented current conditions.

Effective impervious area (EIA) is that portion of impervious area that does not allow stormwater to drain into the soil. In other words, EIA refers to the direct roof-to-street-to-creek connection via paved surface or pipe. The RCIDCM, in an effort to promote reduction in hydraulically connected impervious area, requires the use of EIA in the development of drainage basin design plans. By limiting the EIA during development within a basin, peak stormwater flows, generated stormwater volumes and pollutant loading can be substantially reduced.

The MIA is used within the hydrologic modeling for this amendment. Although the EIA can be approximated per Equation 4.3.1 of the RCIDCM, based on the questionnaire responses received from the neighborhood, the use of MIA was justified. There are stormwater flooding issues within the neighborhood and if the proposed facilities are not sized to accommodate those issues, the City would be held to account by the neighborhood.

Encouraging property owners to redirect downspouts, to use block pavers for driveways and sidewalks or to creatively handle stormwater runoff from their property is prudent and necessary during the development of this plan. Additionally, the City could begin implementing some improvements within neighborhoods that would reduce the EIA (i.e., stormwater quality improvements including bioswales, rain gardens, etc). However, modifications to some City ordinances and policies must still be made to allow some improvements to be made.

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DOVER STREET DRAINAGE IMPROVEMENTS

PHASE II - RED DALE DRAINAGE BASIN DESIGN PLAN AMENDMENT

RAPID CITY, SD

PROJECT NO. DR05-1452, CIP NO. 50025

Sheet Title:

FIGURE 6. OBSERVED FLOWPATHS (WEST)

Sheet:

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FIGURE 7. OBSERVED FLOWPATHS (EAST)

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3.2.2 Time of Concentration

In CUHP, the time to peak (t_p) for a subbasin is calculated as a combination of overland flow and channelized flow. It represents the time required for a drop of rainfall to reach the outfall of a basin from the most remote portion of the basin. The Snyder method use lag time, which is the time difference between the centroid of excess rainfall and the unit hydrograph peak. It utilizes the length of the basin and the length to the basin centroid, as defined in Equation 4.3.2 in the RCIDCM. The lag time calculation includes a lag time coefficient (C_t), which represents variations in watershed slope and storage based on land cover. Due to the complexity of the redelineated subbasins, as well as to utilize existing information for the west and north subbasins, the time of concentration was calculated by determining the overland travel time and channelized travel time. To convert the calculated time of concentration to lag time, the SCS unit hydrograph lag time equation ($t_{lag} = 0.6*t_p$) was used.

The validity of the lag time conversion assumption was investigated for Subbasins 106, 128 and 262. Using Equation 4.3.2, the length of flowpath and length to centroid were measured in each of the three basins. Using a lag time coefficient of 0.6 (urban sewered) for Subbasins 106 and 128, the Synder lag time is 0.189 hours and 0.134 hours, respectively. The lag times used in this DBDPA for the same basins are 0.152 and 0.135 hours, respectively. The lag time coefficient of 0.8 (foothills) was used for Subbasin 262 and yielded a lag time of 0.45 hours; this DBDPA used 0.41 hours. This comparison shows that the SCS lag time equation yields slightly more conservative lag times (~2 minutes faster) than the Synder lag time calculation. Lag time calculations are provided at the end of Appendix A.

3.2.3 Initial Abstraction

The main hydrologic modeling differences between the CUHP and HEC-HMS platforms are the initial abstraction and the infiltration methodology. Under CUHP modeling, initial abstractions range from 0.1 inches for impervious areas and up to 0.4 inches for pervious areas per the 1989 RCDCM. Under the draft RCIDCM, the pervious area abstraction recommended values range from 0.35 for lawns to 0.80 for undeveloped forest. Per the 1989 RCDCM, an initial abstraction of 0.1 inches is used for impervious areas. The pervious fraction of each subbasin was then further detailed into Lawn and Grass, Open Fields and Undeveloped Forest by utilizing orthophotography. The RCIDCM recommended values of 0.35, 0.40 and 0.80 were applied to each land cover type and then all land covers were weight averaged by their respective areas to derive the subbasin initial abstraction.

Using the MIA discussed above, initial abstraction was determined by area-weighting the pervious and impervious area within each subbasin. Table 1 shows a comparison of the initial abstraction values utilized in the CUHP models and the values used in HEC-HMS for the subbasins north and west of Canyon Lake Drive. The area-weighted average percent difference, excluding Subbasin 304, between the initial abstractions used in the CUHP modeling versus the HEC-HMS modeling is -3.49%. The area-weighted average increase in initial abstraction for this study was approximately 0.02 inches for HEC-HMS.

Table 1. Initial Abstraction Comparison Between CUHP and HEC-HMS

BASIN ID	ORIG ID	Initial Abstraction (in) CUHP	HEC-HMS	% Diff	BASIN ID	ORIG ID	Initial Abstraction (in) CUHP	HEC-HMS	% Diff
250	26	0.1840	0.1950	6.0%	**280**	19	0.3930	0.3450	-12.2%
252	27	0.2090	0.2330	11.5%	**282**	18	0.3490	0.3040	-12.9%
254	29	0.2676	0.2730	2.0%	**284**	15	0.3152	0.3940	25.0%
256	28	0.2143	0.2330	8.7%	**286**	16	0.2777	0.2800	0.8%
258	30	0.3412	0.3560	4.3%	**288**	68	0.2393	0.2480	3.6%
260	31	0.2452	0.3800	55.0%	**290**	67	0.2640	0.2740	3.8%
262	36	0.3825	0.2560	-33.1%	**292**	66	0.3262	0.3340	2.4%
266	35	0.3860	0.2920	-24.4%	**294**	65	0.3470	0.3580	3.2%
268	34	0.3552	0.3080	-13.3%	**296**	64	0.3910	0.2980	-23.8%
270	33	0.2720	0.2800	2.9%	**298**	63	0.3668	0.3860	5.2%
272	32	0.3094	0.3530	14.1%	**300**	61	0.3850	0.3760	-2.3%
274	25	0.3060	0.3780	23.5%	**302**	62	0.2780	0.3850	38.5%
276	14	0.2711	0.2810	3.7%	**304**	37	0.3895	0.3850	-1.2%
278	17	0.3930	0.3890	-1.0%	***AREA WTD AVE % DIFF***				***-3.49%***

3.2.4 Rainfall

Rainfall input has changed from a single point value with the NOAA 1-hour design storm distribution used in the CUHP methodology to a frequency-based precipitation model. Incremental rainfall depth values from five minutes to two hours were used in the hydrologic modeling. A time step for the development of the design storm was set to five minutes.

The storm peak was set to occur at the first quartile. Additional discussion of the frequency-based precipitation model is described in the HEC-HMS Users Manual.

3.2.5 Infiltration

The CUHP infiltration method is the empirically-based Horton's infiltration equation that uses the Hydrologic Soils Group (HSG), where HSG A has the highest infiltration/lowest runoff potential and HSG D has the lowest infiltration/highest runoff potential. Figure 8 shows the hydrologic soils groups for the study area. Horton's infiltration equation parameters include initial and saturated infiltration rates and a soil-specific decay constant. These parameters are discussed in the RCIDCM.

HEC-HMS utilizes the Green-Ampt equation, a physically-based infiltration model that uses soil texture as defined by the Unified Soils Classification based. Both HSG and texture can be retrieved from the Natural Resources Conservation Service (NRCS) SSURGO database. Parameters used in the Green-Ampt equation include initial moisture deficit (effective porosity minus the field capacity), suction head and hydraulic conductivity. These parameters are discussed in the RCIDCM.

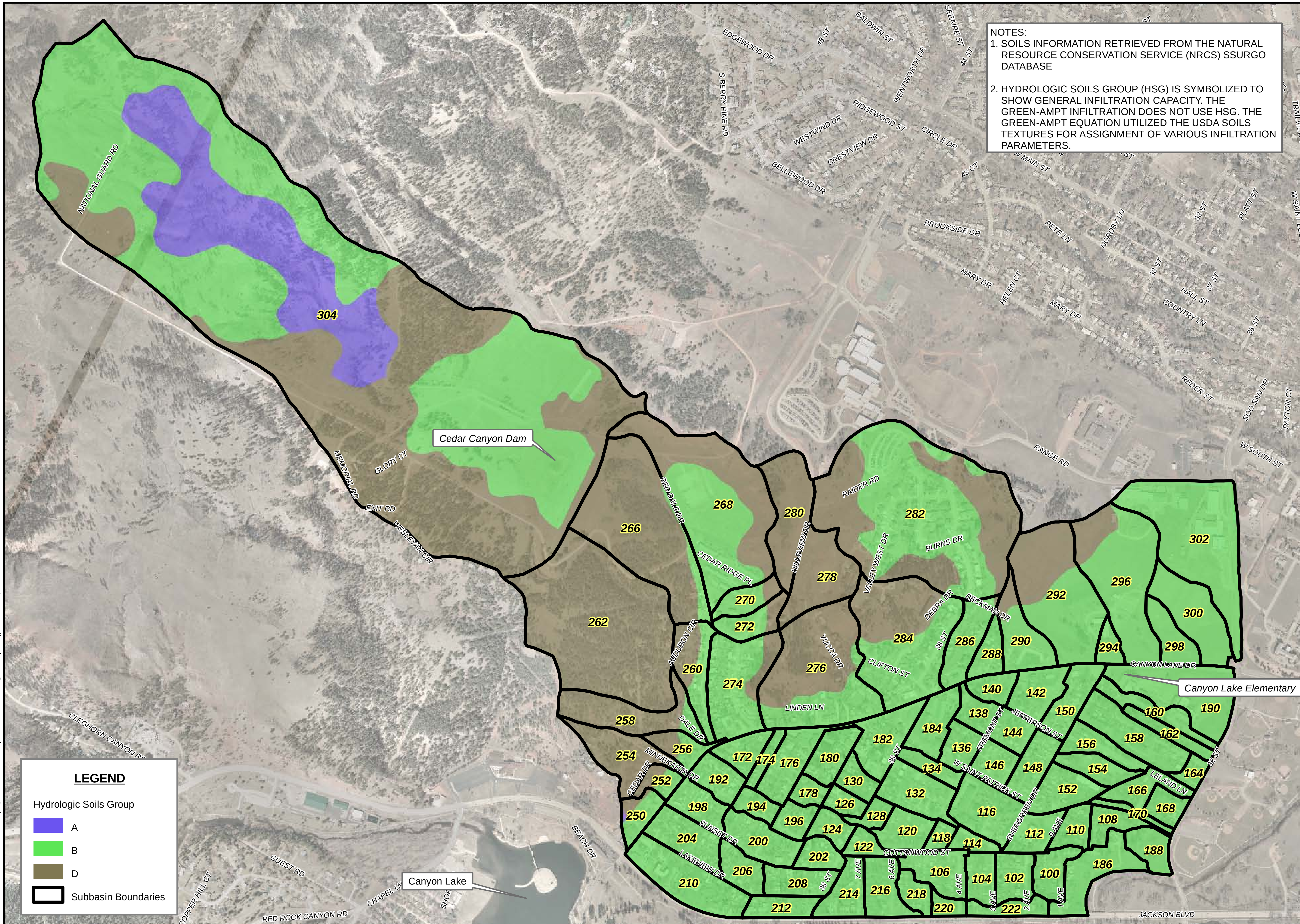
Using either infiltration method, weight-averaged infiltration parameters are determined within each subbasin based on the incremental area of each soil classification. The modeled difference between total rainfall and infiltrated rainfall (that portion of rainfall that is allowed to soak into the ground surface) is excess precipitation. Table 2 presents a comparison of modeled excess precipitation generated by both CUHP and HEC-HMS for the 100-year event. Excess rainfall is that portion of the design rainfall left that contributes to runoff only after initial abstractions and infiltration have been accounted for through the modeling.

Table 2. 100-Year Excess Rainfall Comparison between CUHP and HEC-HMS

BASIN	*Excess Precipitation (inches)*			BASIN	*Excess Precipitation (inches)*		
ID	CUHP	HEC-HMS	% Diff	ID	CUHP	HEC-HMS	% Diff
250	2.63	2.65	0.8%	280	1.93	2.06	6.7%
252	2.54	2.53	-0.4%	282	2.05	2.17	5.9%
254	2.34	2.38	1.7%	284	2.05	2.16	5.4%
256	2.53	1.96	-22.5%	286	2.19	2.34	6.8%
258	2.05	0.68	-66.8%	288	2.45	2.48	1.2%
260	2.42	2.07	-14.5%	290	2.43	2.43	0.0%
262	1.97	0.15	-92.4%	292	2.18	2.20	0.9%
266	1.95	1.93	-1.0%	294	1.90	2.09	10.0%
268	1.92	2.21	15.1%	296	1.77	2.05	15.8%
270	2.25	2.42	7.6%	298	1.85	2.03	9.7%
272	2.10	2.28	8.6%	300	1.79	2.01	12.3%
274	2.04	2.22	8.8%	302	2.23	2.31	3.6%
276	2.34	2.38	1.7%	304	1.94	0.73	-62.4%
278	1.93	2.02	4.7%	***AREA WTD AVE % DIFF =***			***-5.50%***

The infiltration methodology appears to play a significant role in the variability of excess rainfall between CUHP and HEC-HMS. As shown in Table 2, the excess rainfall differences ranged from a runoff reduction of 92.4% to a runoff increase of 15.8% (this increase was seen in Subbasin 280, which is a relatively small basin). Overall, the area-weighted average difference in excess precipitation (runoff volume) is -5.5%, with Subbasin 304 excluded.

Table 3 shows the comparison of the 100-year peak flows for CUHP and HEC-HMS for the same unrevised subbasins. Table 3 shows that out of the 27 basins, 14 basins actually saw an increase in peak flow with an area-weighted average increase of approximately 40% and a range of 1.1% to 100.5% (this increase was seen in Subbasin 280, which is a relatively small basin). Thirteen basins realized reductions in peak flow reductions ranging between -4.2% and -96.4% with an average percent reduction of -35.8%. For the 27 subbasins investigated, the overall area-weighted average 100-year peak flow increased by approximately 3.72% (Subbasin 304 excluded) in the conversion from CUHP to HEC-HMS. With Subbasin 304 included, the overall area-weighted average peak flow for the original subbasins is -19.6%. Subbasin 304 is excluded from comparison due to its limited effect on the overall drainage system for events up to and including the 100-year rainfall.



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RAPID CITY, SD

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Sheet Title:
FIGURE 8. HYDROLOGIC SOILS CLASSIFICATION

Sheet: 27

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Table 3. 100-Year Discharge Comparison Between CUHP and HEC-HMS

BASIN	*Peak Runoff (CFS)*			BASIN	*Peak Runoff (CFS)*		
ID	CUHP	HEC-HMS	% DIFF	ID	CUHP	HEC-HMS	% DIFF
250	13	19	44.6%	280	22	44	100.5%
252	12	12	-4.2%	282	162	226	39.3%
254	35	35	1.1%	284	69	109	58.6%
256	14	16	12.1%	286	19	30	60.0%
258	29	9	-68.6%	288	16	15	-8.1%
260	28	28	1.1%	290	26	20	-24.6%
262	191	7	-96.4%	292	71	45	-36.9%
266	74	119	61.4%	294	10	11	5.0%
268	127	143	12.4%	296	55	42	-23.8%
270	12	10	-16.7%	298	12	8	-35.0%
272	19	21	10.0%	300	20	17	-14.5%
274	84	62	-26.8%	302	133	96	-28.0%
276	77	117	51.6%	304	484	244	-49.7%
278	25	27	6.8%	***AREA WTD AVE % DIFF =***			***3.72%***

Some difference in peak flow can be explained by the Snyder Method peaking coefficient, C_p, which represents flood wave routing and storage conditions within the basin. Essentially, the flatter the basin slope, the slower stormwater moves, which allows additional infiltration. CUHP does not require direct input of this value; it is back-calculated from the basin length, basin length to centroid and basin slope. A quick review of the original CUHP results shows that the back-calculated C_p-values ranged from 0.121 to 0.323. The RCIDCM suggests C_p-values ranging between 0.4 to 0.8 with a recommended value of 0.6. In this study, all basins east of Canyon Lake Drive used C_p equal to 0.6; all basins to the west used C_p equal to 0.7. This partially explains peak flows being higher than the original DBDP.

Another reason for some of the decreases in excess rainfall and peak flows is associated with rainfall estimation. CUHP used the one hour rainfall event transformed using the NOAA 1-hour design storm distribution. The storm distribution ordinates sum to 115.7%. To correct this, typically an adjustment called redistribution is completed. However, CUHP does not make the redistribution adjustment. Therefore, the 100-year rainfall depth of 2.95 inches was actually modeled as 3.41 inches. This example shows that the modeled rainfall in CUHP is approximately 16% higher than calculated in HEC-HMS.

3.3 Subbasin Hydrologic Summary

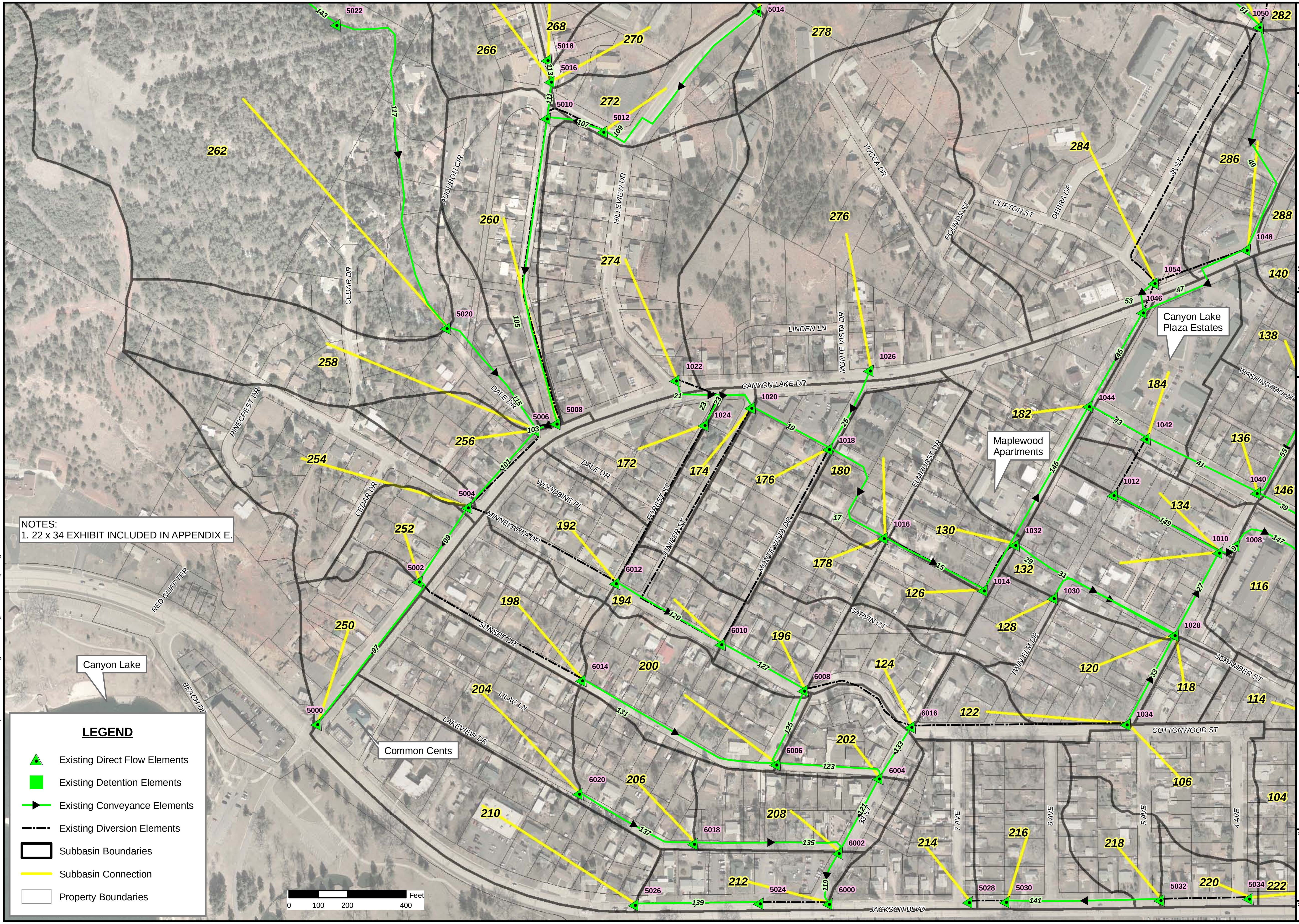
The HEC-HMS subbasin input information is provided in Appendix A along with subbasin hydrographs generated for the 2-, 10- and 100-year events. Table 4 presents the DBDPA peak discharges for the subbasins. Table 5 presents the DBDPA runoff volumes for the subbasins. Figures 9 and 10 show the existing conditions hydrologic schematics. Figures 11 and 12 show the DBDPA hydrologic schematics developed for and referred to in the Hydraulic Updates section of this study. Larger versions of these figures are provided in Appendix E. The study area is shown as east half and west half in the figures and exhibits to facilitate interpretation.

Table 4. HEC-HMS DBDPA Subbasin Peak Discharges for 2-, 10- and 100-year Rainfall

Basin	Peak Discharge (cfs)			Basin	Peak Discharge (cfs)			Basin	Peak Discharge (cfs)		
	2-YR	10-YR	100-YR		2-YR	10-YR	100-YR		2-YR	10-YR	100-YR
100	4	10	17	160	4	9	17	220	1	3	6
102	4	10	18	162	2	6	11	222	3	8	13
104	3	8	15	164	1	4	6	250	5	11	18
106	5	13	23	166	4	10	17	252	2	6	11
108	3	8	14	168	3	7	13	254	5	17	31
110	3	7	12	170	1	4	7	256	4	6	10
112	5	11	19	172	3	8	15	258	1	2	3
114	2	5	9	174	2	5	9	260	5	9	21
116	8	20	34	176	6	15	27	262	2	18	65
118	1	4	7	178	2	5	9	266	2	24	81
120	4	10	18	180	4	11	19	268	9	56	119
122	3	6	9	182	7	17	30	270	2	5	9
124	3	7	12	184	6	13	22	272	3	10	18
126	2	5	10	186	2	14	28	274	6	27	54
128	2	5	9	188	1	7	14	276	17	55	103
130	3	7	13	190	7	24	47	278	0	8	20
132	6	16	29	192	4	10	18	280	0	14	35
134	1	7	13	194	2	5	10	282	10	82	182
136	3	9	15	196	3	7	13	284	10	45	93
138	3	7	12	198	4	10	18	286	4	14	27
140	3	8	13	200	5	15	26	288	3	8	13
142	7	15	25	202	3	7	13	290	3	9	17
144	4	9	16	204	5	15	26	292	4	15	35
146	3	9	15	206	3	8	15	294	1	4	9
148	4	11	20	208	4	10	18	296	1	10	29
150	5	12	21	210	10	24	41	298	0	2	6
152	6	15	26	212	4	9	16	300	0	4	12
154	3	8	15	214	4	12	21	302	14	44	84
156	4	10	18	216	4	11	20	304	8	15	23
158	8	20	35	218	3	7	12				

Table 5. HEC-HMS DBDPA Subbasin Runoff Volumes for 2-, 10- and 100-year Rainfall

Basin	Runoff Volumes (ac-ft)			Basin	Runoff Volumes (ac-ft)			Basin	Runoff Volumes (ac-ft)		
	2-YR	10-YR	100-YR		2-YR	10-YR	100-YR		2-YR	10-YR	100-YR
100	0.2	0.5	0.8	**160**	0.2	0.5	0.8	**220**	0.1	0.2	0.3
102	0.2	0.5	0.8	**162**	0.1	0.3	0.5	**222**	0.1	0.3	0.5
104	0.2	0.4	0.7	**164**	0.1	0.2	0.3	**250**	0.2	0.4	0.7
106	0.3	0.6	1.1	**166**	0.2	0.5	0.8	**252**	0.1	0.2	0.4
108	0.2	0.4	0.7	**168**	0.1	0.3	0.5	**254**	0.3	0.8	1.4
110	0.1	0.3	0.5	**170**	0.1	0.2	0.3	**256**	0.1	0.3	0.5
112	0.2	0.5	0.8	**172**	0.2	0.4	0.7	**258**	0.1	0.1	0.5
114	0.1	0.2	0.4	**174**	0.1	0.2	0.4	**260**	0.2	0.6	1.1
116	0.4	0.9	1.5	**176**	0.3	0.7	1.2	**262**	0.2	0.3	0.5
118	0.1	0.2	0.3	**178**	0.1	0.2	0.4	**266**	0.4	2.1	4.3
120	0.2	0.5	0.8	**180**	0.2	0.5	0.8	**268**	0.9	2.9	5.5
122	0.1	0.3	0.4	**182**	0.4	0.8	1.4	**270**	0.1	0.4	0.6
124	0.1	0.3	0.5	**184**	0.3	0.6	1.0	**272**	0.1	0.4	0.7
126	0.1	0.2	0.4	**186**	0.2	0.7	1.3	**274**	0.4	1.2	2.2
128	0.1	0.2	0.4	**188**	0.1	0.3	0.6	**276**	1.0	2.6	4.6
130	0.1	0.3	0.5	**190**	0.5	1.3	2.4	**278**	0.1	0.7	1.5
132	0.3	0.8	1.3	**192**	0.2	0.5	0.8	**280**	0.2	0.8	1.6
134	0.1	0.3	0.5	**194**	0.1	0.2	0.4	**282**	1.4	5.1	9.7
136	0.2	0.4	0.7	**196**	0.1	0.3	0.5	**284**	0.6	2.1	4.0
138	0.1	0.3	0.5	**198**	0.2	0.5	0.8	**286**	0.2	0.6	1.1
140	0.1	0.3	0.5	**200**	0.3	0.7	1.2	**288**	0.1	0.3	0.5
142	0.3	0.7	1.1	**202**	0.1	0.3	0.5	**290**	0.3	0.7	1.3
144	0.2	0.4	0.7	**204**	0.3	0.7	1.2	**292**	0.6	1.8	3.4
146	0.2	0.4	0.7	**206**	0.2	0.4	0.7	**294**	0	0.2	0.3
148	0.2	0.5	0.9	**208**	0.2	0.5	0.8	**296**	0.4	1.6	3.2
150	0.3	0.6	1.0	**210**	0.5	1.2	2.1	**298**	0.1	0.3	0.6
152	0.3	0.6	1.1	**212**	0.2	0.4	0.7	**300**	0.2	0.7	1.5
154	0.2	0.4	0.7	**214**	0.2	0.5	0.9	**302**	0.8	2.3	4.2
156	0.2	0.5	0.8	**216**	0.2	0.5	0.9	**304**	0.7	3.2	16.6
158	0.4	1.0	1.6	**218**	0.1	0.3	0.5				



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RAPID CITY, SD

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Sheet Title:

FIGURE 9.
EXISTING CONDITION
HYDROLOGIC
SCHEMATIC

Sheet:
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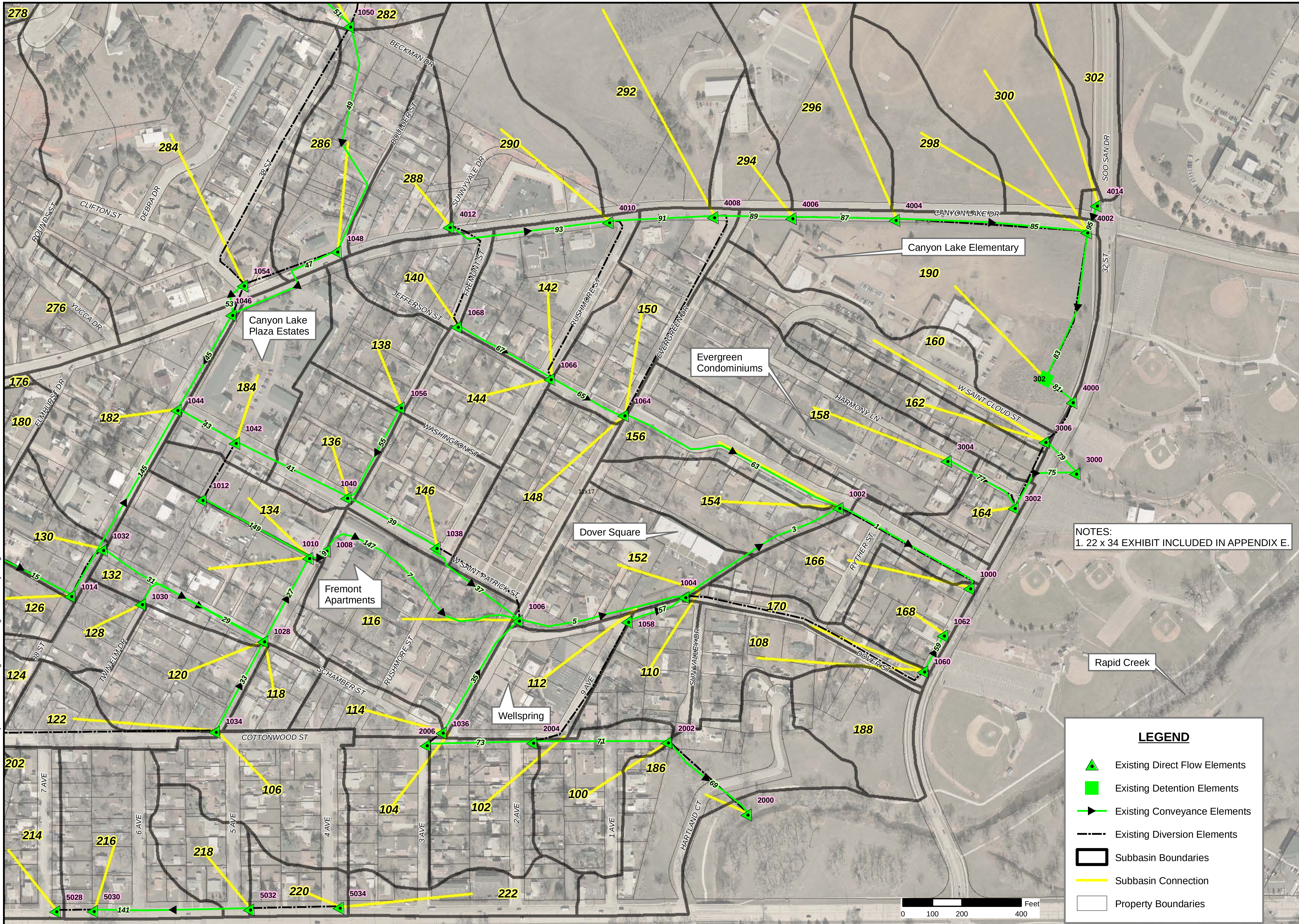

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Sheet Title:

FIGURE 10.
EXISTING CONDITION HYDROLOGIC SCHEMATIC

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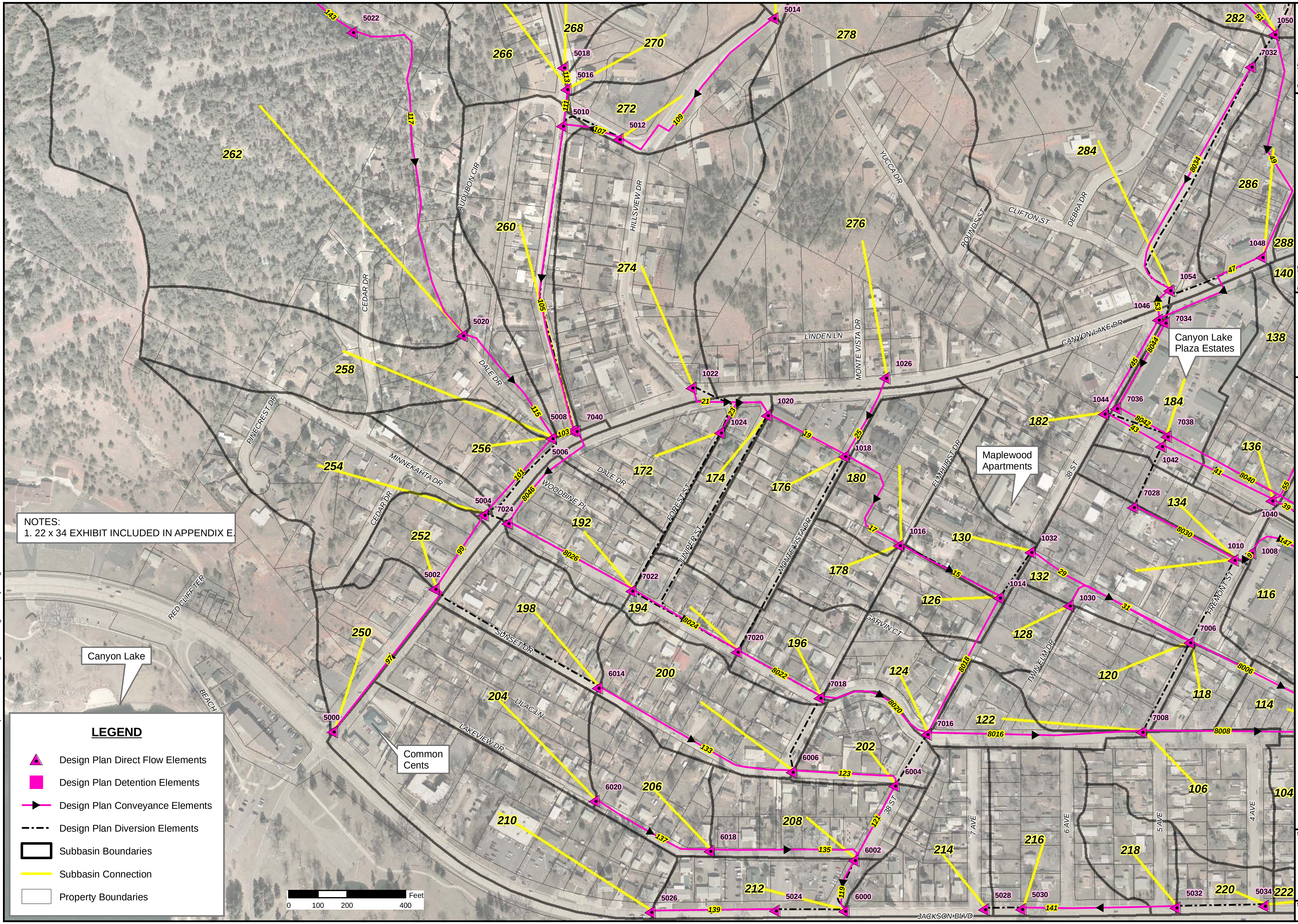

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DATE: 2/8/2010

Prepared For: Rapid City, South Dakota

Prepared By: Ferber Engineering Company, Inc.
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DOVER STREET DRAINAGE IMPROVEMENTS

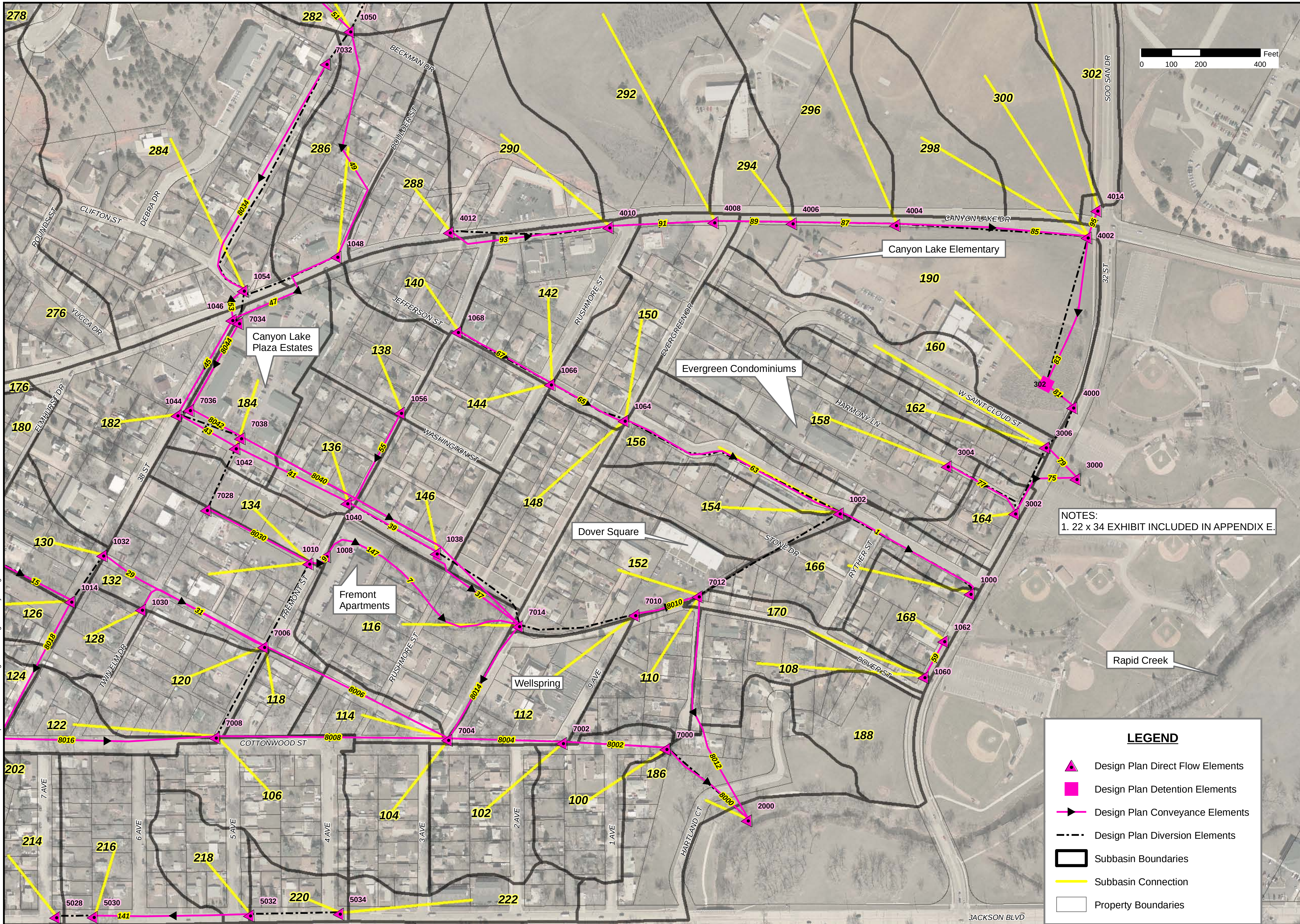
PHASE II - RED DALE DRAINAGE BASIN DESIGN PLAN AMENDMENT

RAPID CITY, SD

PROJECT NO. DR05-1452, CIP NO. 50025

Sheet Title: FIGURE 11. DESIGN PLAN HYDROLOGIC SCHEMATIC

Sheet: 33



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RAPID CITY, SD

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Sheet Title:

FIGURE 12.
DESIGN PLAN
HYDROLOGIC
SCHEMATIC

Sheet:
34

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DATE: 2/8/2010

4.0 Hydraulic Updates

The DBDPA improvements suggested in this plan and outlined below substantially change the nature of drainage patterns within the study area. The existing contributing areas the six general outfalls are presented in Section 2. Figure 2 shows the contributing areas for the existing hydraulic conditions. Figure 3 shows the contributing areas for the DBDPA hydraulic conditions. Table 6 shows the amount of contributing area that the DBDPA facilities redirect to the proposed Hartland Court Stormwater Quality Facility.

Table 6. Change in Contributing Area by Constructing DBDPA Facilities

General Outfall	Contributing Area (acres) Existing Hydraulics	DBDPA Hydraulics	Change
Cedar Canyon Dam	272	272	0
Canyon Lake Elementary	95	65	-30
32nd Street	265	56	-209
Jackson Boulevard	65	54	-11
Park Drive	144	135	-9
Hartland Court	**17**	**276**	**+259**

The following text outlines how the facilities function to make the revisions shown above.

4.1 Methodology

The HEC-HMS model provides a selection of hydraulic modeling methodologies. The Muskingum-Cunge routing method was used in the completion of this study. A discussion of the Muskingum-Cunge routing method is provided in the RCIDCM.

Existing hydraulic conditions and design plan hydraulic conditions were both analyzed using fully-developed flow conditions. The hydraulic schematization of both the existing and design plan facilities within this study is more detailed than the original DBDP. The additional detail within the modeling reflects field collected information and observed flow splits. The additional detail allows the model to accurately reflect field conditions.

The HEC-HMS model platform uses hydraulic characteristics of the individual conveyance elements to create time-delayed routing of the flows through the system. ***Users of this report are cautioned that while flow depths are calculated for each conveyance element, these depths are based upon simplified hydraulic properties. Each element must be designed using accepted hydraulic engineering practice.***

Modeling Parameters:

Conveyance element input data is provided in Appendix B. Unlike UDSWMM which required an increase of 25% for the Manning's n roughness values, HEC-HMS does not require the same Manning's n increases. UDSWMM utilized the kinematic wave routing routine adapted from the EPA's Stormwater Management Model (SWMM). HEC-HMS allows hydraulic modeling to be performed by several different methods, including the kinematic wave option.

Hydraulic modeling for this DBDPA utilized the Muskingum-Cunge method for the following geometric shapes:

- Rectangular Channel
- Trapezoidal Channel
- Triangular Channel
- Irregular Channel (limited to eight input points)
- Round Pipe
- Box Pipe

The HEC-HMS model for this study was developed with more regard to reality due to the flexibility of the inputs. Therefore, recommended box culverts are actually modeled as box culverts. In UDSWMM, a box culvert was modeled as an equivalent diameter round pipe.

Diversion elements were used within the HEC-HMS modeling to approximate the flow splits/diversions that are currently occurring in the neighborhood. HEC-HMS uses rating curves of total flow versus diverted flow to determine how much flow during a specific rainfall event stays in the main conveyance and how much flow is diverted to another location. Rating curves for the diversions within this plan were developed from field observed conditions during runoff events and using digital aerial topography for approximate elevations.

Additional analysis was performed on the open channel and street elements using Bentley's FLOWMASTER™ software. This software was used to develop the flow depths and velocities provided in the element descriptions. It was also used to develop the rating curves for the diversion elements used in the model.

Although the HEC-HMS model platform allows the user to provide more geometric detail, the recommended facilities are still **conceptual** in nature and require additional modeling during final design using a program such as the EPA's Storm Water Management Model (SWMM) or similar program. These more robust hydraulic models allow the user to interpret complex flow conditions, water surface elevations and hydraulic and energy grade lines. HEC-HMS does not provide this level of analysis.