

**GIECK RANCH
DRAINAGE BASIN PLANNING STUDY
El Paso County, Colorado**

Volume 1 – Final Report

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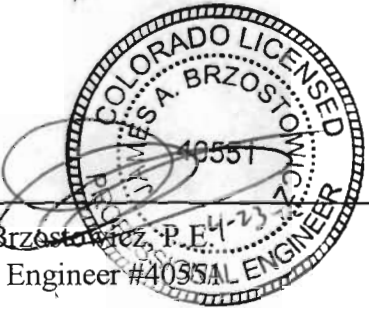
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Professional Engineer’s Certification:

The attached GIECK RANCH DRAINAGE BASIN PLANNING STUDY was prepared under my direction and supervision and is correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the County for drainage reports. I accept responsibility for any liability caused by any negligent acts, errors and omissions on my part in preparing this report.

Drexel, Barrell & Company, 3 South 7th Street, Colorado Springs, CO 80905


James A. Brzostowicz, P.E.
Registered Engineer #40551

April 23, 2010
Date

Executive Summary

The Gieck Ranch basin covers a total area of 22.05 square miles within unincorporated El Paso County. The basin begins approximately five miles northeast of the Town of Falcon in El Paso County at an elevation of approximately 7,300 feet. From this point, drainage from the basin travels approximately 15 miles to the southeast. In general, steeper slopes are located at the northern reaches of the basin, while the flatter slopes are located at the southern reaches. The Gieck Ranch Drainage Basin is tributary to Black Squirrel Creek which drains south to its confluence with the Arkansas River near the city of Pueblo, Colorado. The majority of the area within the basin is undeveloped and is characterized as rolling range land typically associated with Colorado’s semi-arid climates.

Existing and proposed development within the Gieck Ranch Drainage Basin have generated the requirement for master planning of the drainage infrastructure. If left unchecked, runoff from the basin will increase in frequency and magnitude as the basin is developed and the impervious area is increased. Over a period of time damage to existing drainage facilities could occur as a result of the increased flows and runoff velocities. Such adverse impacts could include an expansion of the floodplain, chronic erosion of the channel bottom and banks, and potential damage to drainage structures and property due to increased runoff, velocity, and runoff volume from even minor rainfall events. The purpose of this report is to address these impacts and to prepare a feasible stormwater management plan to meet the future needs of the basin.

This report includes information on the hydrologic analysis for both the existing and future conditions. The most current topographical information available was used to delineate watershed basins and identify channel characteristics. Land use data from various sources was used along with soils information to estimate runoff volumes for 2-, 5-, 10-, and 100-year, 24-hour frequency storms for the existing and future conditions. The results of the runoff analysis were then compared to other studies and alternative methods of peak flow estimations.

This report also includes the results of the existing and proposed conditions hydraulic analysis, existing drainage structure inventory and structure deficiency information and the results of an environmental

evaluation. The hydraulic analysis results were used as part of an alternatives analysis to determine the recommended improvements for mitigating development impacts that are presented in the selected plan. The alternatives analysis was presented and discussed at a stakeholders meeting held on June 6, 2007 at the El Paso County Department of Transportation office. Small regional ponds utilizing full spectrum detention was selected at this meeting as the primary alternative for reducing peak flows. Full spectrum detention is a fairly new concept whereas the difference in pre- and post-development runoff volume is detained and released slowly over a 72 hour period. This method controls peak flow rates for the full spectrum of runoff events from the smallest up to the 100-year event. It was first introduced by the Urban Drainage and Flood Control District in 2005 and has since been included in their updated Drainage Criteria Manual. Selected channel improvements include vegetation augmentation, selective stabilization and the use of grass-lined channels. These selected alternatives are designed to minimize the environmental impacts of development on the drainage basin. The armoring of channels has been minimized through the use of bio-engineered channels and grade control structures.

The existing drainage structure inventory and evaluation revealed that the majority of the culverts and some of the bridges throughout the basin are undersized, even for existing conditions flows. Replacement structures are recommended and prioritized as part of the selected plan. Cost estimates were generated based on the recommended improvements called out on the plan view drawings in Appendix A. The cost estimates, which were used to determine drainage basis fees, include a 20% contingency and 10% engineering cost. No costs attributable to local or minor drainage systems have been included in the estimation of the drainage basin fees. The fees shown in the following table were calculated on a per impervious acre basis. A total of 13,749 acres is estimated to be currently unplatted and subject to future development. This unplatted land is projected to have an average imperviousness of 9.5% based on 2030 land uses, corresponding to 1,306 unplatted impervious acres on which the fees shown in Table ES-1 are based.

Table ES-1: Drainage Basin Fees

Fee Component	Total Cost	Fee Per Impervious Acre
Drainage Fee	\$19,049,632	\$14,586
Bridge Fee	\$1,756,560	\$1,345
Land Acquisition fee	\$1,782,000	\$1,364
Total All Fees	\$22,588,192	\$17,296

I. Introduction

A. Contract Authorization

The Drainage Basin Planning Study (DBPS) for Gieck Ranch (a.k.a. Geick Ranch) is being performed by Drexel, Barrell and Co. under contract with Reality Development Services. This report provides information on the hydrologic and hydraulic analyses conducted for the Gieck Ranch Drainage Basin and its major tributaries located northeast of Colorado Springs, Colorado in unincorporated El Paso County.

B. Purpose and Scope of Study

The purpose of this study is to evaluate existing and future drainage conditions, identify corrective and future capacity improvements and to establish drainage basin and bridge fees for the Gieck Ranch Drainage Basin. The report is designed to act as a master plan for the feasible implementation of stormwater management within the basin. The plan also creates the justification and forms the basis for a future drainage basin and bridge fee. The fee will be applied as part of El Paso County's drainage basin fee system.

As defined by El Paso County and in conjunction with County personnel, the following summarizes the scope of work that has been defined for this project:

Phase 1: Scoping and Stakeholder Involvement

1. Meet with County personnel to finalize technical scope of work and to establish the general criteria for preparation of the report.
2. Contact and meet with the County and other individuals (stakeholders) that would have knowledge or interest in the development of the basin.

Phase 2: Problem Identification/Existing and Future Conditions

1. Gather all basin technical information necessary to conduct the study.
2. Perform a hydrologic analysis of the basin to determine existing and future runoff.

3. Using runoff amounts from the hydrologic model perform a hydraulic analysis of the basin for existing and developed conditions.
4. Identify existing and potential drainage and/or flooding problems within the basin.

Phase 3: Alternatives Development, Evaluation and Selection

1. Identify and map environmentally significant areas.
2. Develop improvement alternatives to address and reduce existing and future drainage and flooding problems within the basin.
3. Meet with individuals and organizations with an interest in the basin to define project goals and to help develop the selected alternative.
4. Examine the feasibility of each alternative and develop an economic analysis to arrive at the selected alternative used in this report.

Phase 4: Plan Development

1. Prepare a plan and profile design showing proposed improvements for each outfall system or major drainageway defined in the study.
2. Develop cost estimates for all improvements.
3. Prepare a Drainage Basin Plan Report of the study findings and the selected improvements for approval by the Sponsors and Stakeholders.

Phase 5: Fee Development

1. Based on costs from the approved Drainage Basin Plan Report, develop drainage basin and bridge fees for the basin.

Phase 6: Plan Adoption

1. Submit the Drainage Basin Plan to County Commissions and other jurisdiction officials as needed for review and adoption.

C. Public Input, Review and Stakeholder Process

A list of stakeholders was developed to identify a list of the agencies, private companies and individuals to be notified of the progress of the DBPS effort, invited to progress meetings, and receive draft technical information for review. A complete mailing list of stakeholders and correspondence received is provided in Section 1 of the Technical Addenda. Project progress evaluation and coordination meetings were held throughout the course of the planning study. Meetings were also scheduled with various agencies and public citizens with an interest in the preparation of this DBPS. Following is a summary of the meetings:

Meeting	Date
Kickoff	March, 2004
Stakeholder	November 9, 2005
Progress	January 18, 2005
Progress	February 15, 2005
Progress	March 14, 2006
Stakeholder	April, 2005
Progress	January 18,2006
Progress	July 5, 2006
Progress	July 6, 2006
Progress	September 6, 2006
Progress	October 3, 2006
Progress	November 8,2006
Progress	January 10, 2007
Progress	April 4, 2007
Progress	May 3, 2007
Public	June 6, 2007

D. Past Studies, Related Investigations, and References

The following is a list of studies, technical reports, and references that were used in the development of this report:

1. *City of Colorado Springs and El Paso County Drainage Criteria Manual*, November 1991.
2. *Urban Drainage and Flood Control District, Urban Storm Drainage Criteria Manual – Volumes I, II, and III*, Wright Water Engineers, Inc., June 2001.
3. *Soil Survey Geographic (SSURGO) database for El Paso County Area, Colorado*, United States Department of Agriculture, Natural Resource Conservation Service, December, 2005.
URL: <http://SoilDataMart.nrcs.usda.gov>

4. *Flood Insurance Study, El Paso County, Colorado and Incorporated Areas*, Federal Emergency Management Agency, August 23, 1999.
5. *NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume III-Colorado*, U.S. Department of Commerce, 1973.
6. *El Paso County Future Landuse and Buildout, 2005*. Obtained from El Paso County Information Technologies.
7. *El Paso County Future Landuse and Buildout, 2030*. Obtained from El Paso County Information Technologies.
8. *El Paso County, Major Transportation Corridors Plan*, El Paso County Planning Department, Adopted September 21, 2004.
9. *Analysis of the Magnitude and Frequency of Floods in Colorado*. U.S. Geological Survey, 2000.
10. *Black Squirrel Creek Hydrologic Analysis*, U.S. Army Corps of Engineers, February 2003.
11. *Guidelines for Determining 100-year Flood Flows for Approximate Floodplains in Colorado, Version 6.0*, Colorado Water Conservation Board, June, 2004.
12. *Technical Release Manual TR-55, Urban Hydrology for Small Watersheds, 2nd Edition*, U.S. Soil Conservation Service, June 1986.
13. *The Master Development Drainage Plan and Preliminary Drainage Report for Four Way Ranch*, revised June 2004.
14. *The Master Development Drainage Plan, Meridian Ranch*, August 21, 2001.
15. *Santa Fe Springs Sketch Plan*, August 8, 2004.
16. *Classification of Wetlands and Deepwater Habitats of the United States*, U.S. Fish and Wildlife Service, 1979.
17. *Colorado Flora – Eastern Slope*, Weber, W. & Wittman, R., 2001.
18. *Corps of Engineers Wetlands Delineation Manual*, U.S. Army Corps of Engineers, 1987.

I. Project Description, Location and Drainage

A. Basin Description and Location

Figure 1.0 shows the location of the Gieck Ranch Drainage Basin. The basin covers a total area of 22.05 square miles within unincorporated El Paso County. The basin begins approximately five miles northeast of the Town of Falcon in El Paso County at an elevation of approximately 7,300 feet above mean sea level (msl). From this point, drainage from the basin travels approximately 15 miles to the southeast. An aerial photograph of the basin is included as Figure 1.1 which is located in Volume 2 of this report. The minimum elevation within the basin is approximately 6,100 feet above msl. Channel slope varies considerably across the basin with average channel slopes ranging from 0.5% to 5%. In general, steeper slopes are located at the northern reaches of the basin, while the flatter slopes are located at the southern reaches. The Gieck Ranch Drainage Basin is tributary to Black Squirrel Creek which drains south to its confluence with the Arkansas River near the city of Pueblo, Colorado. The area encompassing the basin is characterized by rolling range land typically associated with Colorado's semi-arid climates. Existing vegetative cover in undeveloped areas is considered fair for the purposes of this report.

While developing this Drainage Basin Planning Study it was determined that a portion of the adjacent Haegler Ranch Basin, approximately 1.4 square miles, is diverted into the Gieck Ranch Basin as shown in Figure 1.0. This diversion occurs just east and immediately upstream of the intersection of Judge Orr Road and Curtis Road. The diversion exists because no culvert was constructed to convey the runoff from the north side of Judge Orr Road to the south side when the road was originally built. Instead, runoff flows east along the northern edge of the road to a culvert located within the Gieck Basin. This condition has existed since the construction of Judge Orr Road. A stakeholder's meeting was held April, 2005 to discuss the impacts of maintaining the diversion or removing it and restoring historic flows. It was decided to maintain the diversion as is, Documentation and correspondence related to the diversion can be found in Section 1 of the Technical Addenda. In addition to the diversion, while delineating the drainage basins using LIDAR based topography, it was determined that there is an additional 1.35 square miles of area in the southeast section that drains into the Gieck Ranch Basin that

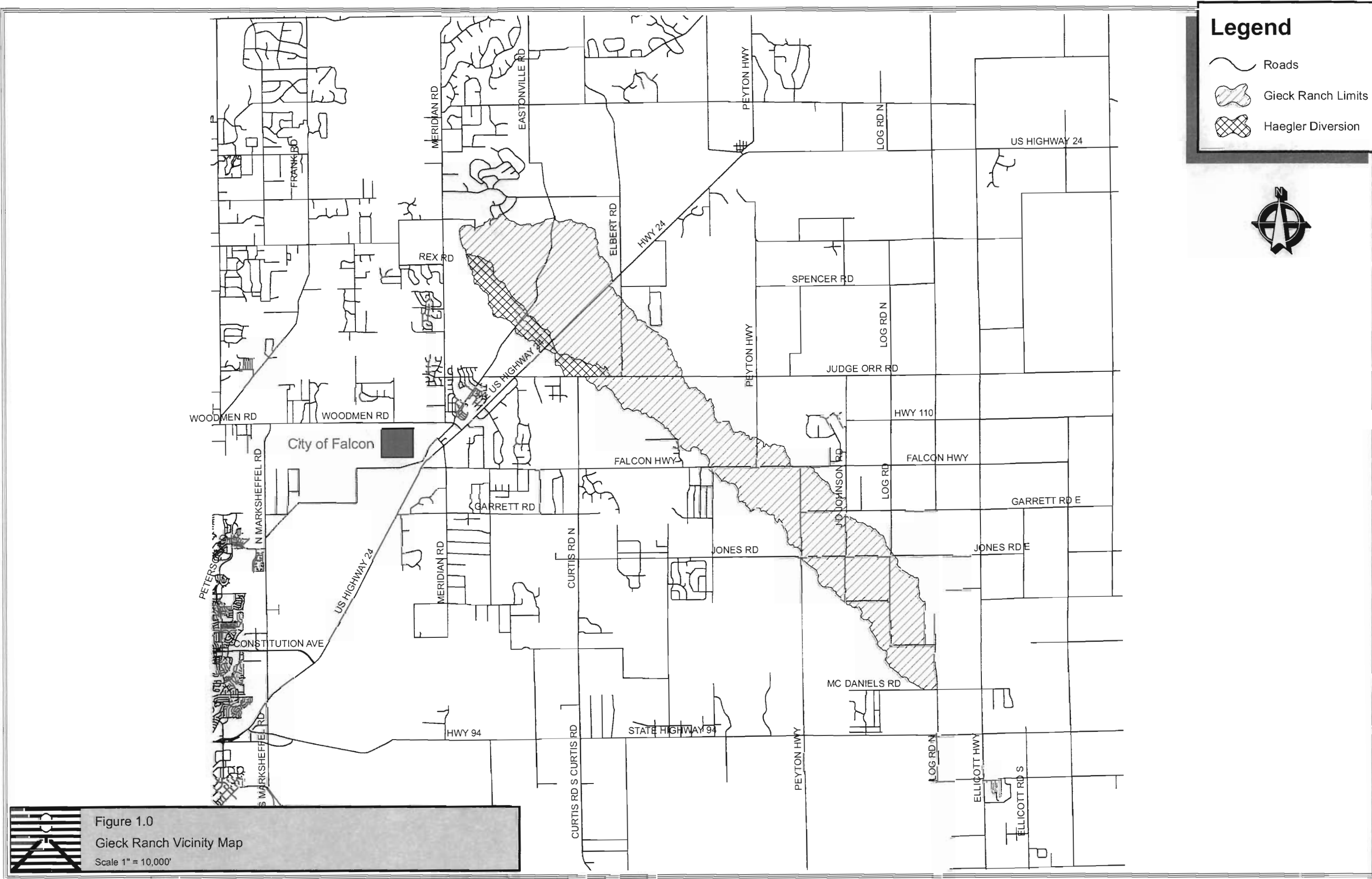
was previously thought to drain into adjacent basins. The total square miles of drainage area for the Gieck Ranch Basin (22.05) includes the 1.4 square miles of drainage area diverted from the Haegler Ranch Basin and the 1.35 square miles of additional drainage area in the southeast section of the basin.

The drainage basin has been subdivided into six major sub-watersheds or drainageways. These include the Main Stem Channel (MS) and five main tributaries, the Haegler Diversion (HD), West Fork (WF), East Fork (EF), South Fork (SF), and Southeast Fork (SE). These major drainageways were determined as those existing drainageways that carry runoff from at least 100 to 160 acres. Figure 2.0 shows the locations of the six main drainageways.

There are several open water storage areas that exist within the basin. They appear to be remnants of former irrigation structures and/or stock watering ponds. They do not appear to be constructed for the purposes of flood control. For modeling purposes they were not evaluated as effective storage. Additionally, remnants of several irrigation facilities associated with former ranch lands can be found within the drainage basin. It is not apparent whether or not these irrigation structures are still used. There do not appear to be any active irrigation ditches within the basin.

B. Climate and Flood History

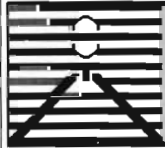
The region surrounding the City of Falcon is generally classified as semi-arid, with annual precipitation in the range of 14 to 16 inches. The bulk of the precipitation is received during the spring and summer months in the form of thundershowers. Most of the flood-producing storms in El Paso County occur during the summer months when thunderstorms are most intense. Available flood history for El Paso County is almost exclusively concerned with the aspects of flooding on Fountain Creek or Monument Creek urbanized areas, so there is no history of flooding in the Gieck Ranch Basin listed in the El Paso County Flood Insurance Study. However, significant flooding events resulting in damage to roadways and drainage structures have been documented in nearby basins, such as that which occurred in the Haegler Basin in 1995. This indicates that flooding and related damage within the Gieck Ranch Drainage Basin and its tributaries is possible in the future.

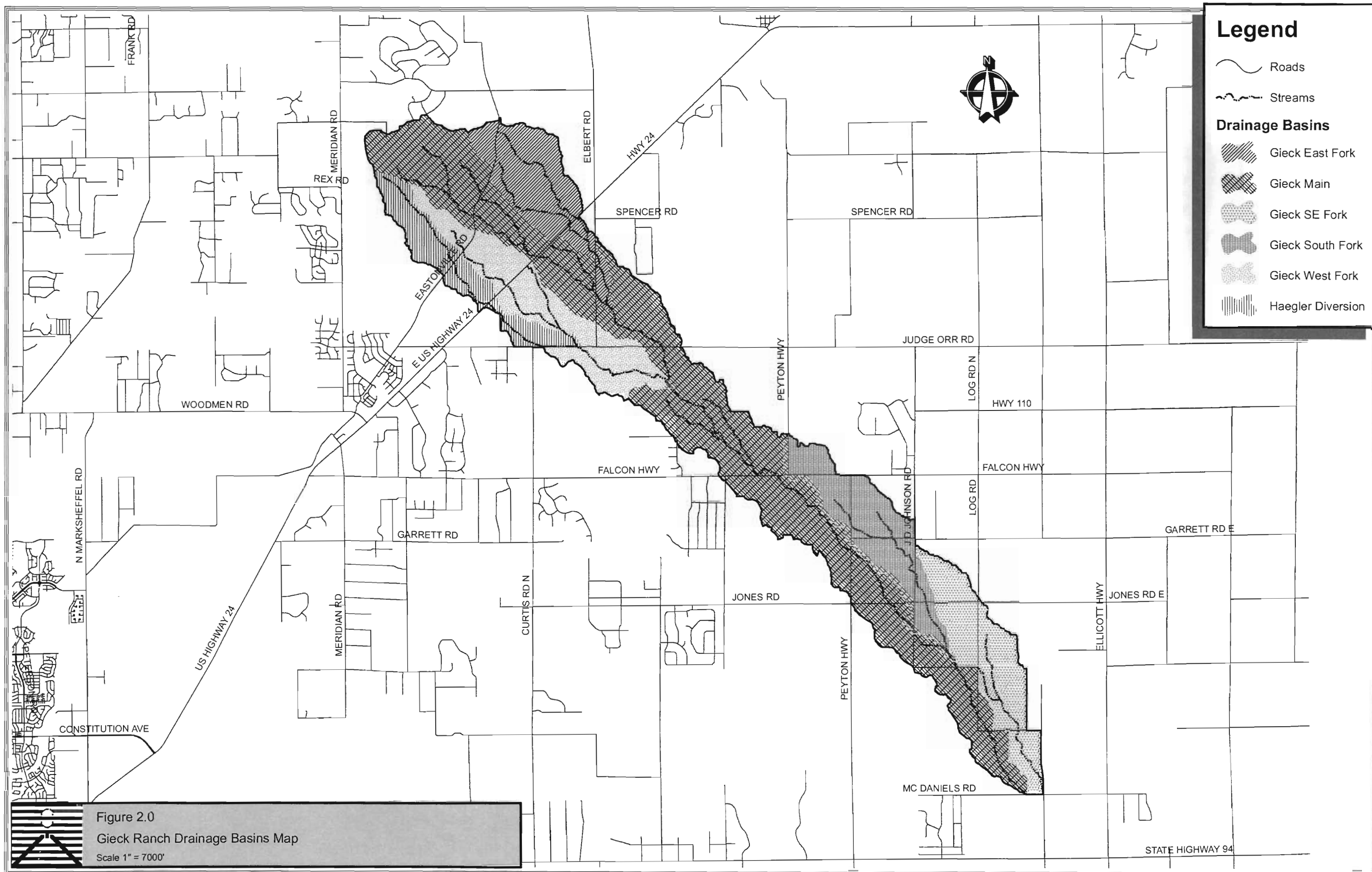


Legend

- Roads
- Gieck Ranch Limits
- Haegler Diversion



 **Figure 1.0**
Gieck Ranch Vicinity Map
Scale 1" = 10,000'



Average temperatures range from about 30°F in the winter months to 75°F in the summer months. Humidity is low, with relative humidity levels ranging from 25% in the summer to 45% in the winter. Due to the low relative humidity levels, evapotranspiration is relatively high compared to the amount of precipitation received in the area. In some areas estimates of 90% to 97% of the precipitation evaporates leading to parched soil and vegetative conditions during the hot summer months.

C. Soils and Geomorphology

Various types of soils exist within the Gieck Ranch Basin. The hydrologic soil groups consist of predominantly types A and B with a small percentage of the soil falling into hydrologic soil group D as shown on Figure 3.0. More detailed soils maps are provided in Figures 3.1, 3.2, and 3.3 which are located in Volume 2 of this report. The location of the soil types were obtained from the “*Soil Survey Geographic (SSURGO) database for El Paso County Area, Colorado*” prepared by the United States Department of Agriculture, Natural Resource Conservation Service. The soil survey data was mapped using ArcGIS computer software.

Blakeland, Columbine, Stapleton, and Truckton soil groupings make up the majority of the soils present in the basin with minor contributions from the Ustic Torrifluvents, Sampson, Pring, Fluvaquentic Haplaquolls, Blendon, and Ellicott soil groupings. The majority of the soils consist of well drained and somewhat excessively drained soils that formed in alluvium and eolian deposits derived from arkosic sedimentary rock. According to the El Paso County soil survey, most of these soils are not suitable for use in water management channels since they erode easily.

Ephemeral streams, characteristic of semiarid regions, are sensitive to changes. In response to a major flood, channel adjustment may be dramatic in character and is often swift in occurrence. An ephemeral stream can change from a small meandering stream to a wide braided channel as a result of a large flooding event. Gieck Ranch is typical of many ephemeral streams in that the channel tends to meander over a period of years. Historic evidence of meandering is predominant in the lower reaches where there is relatively less topographic relief and the channel broadens and becomes shallow, wide and sandy.

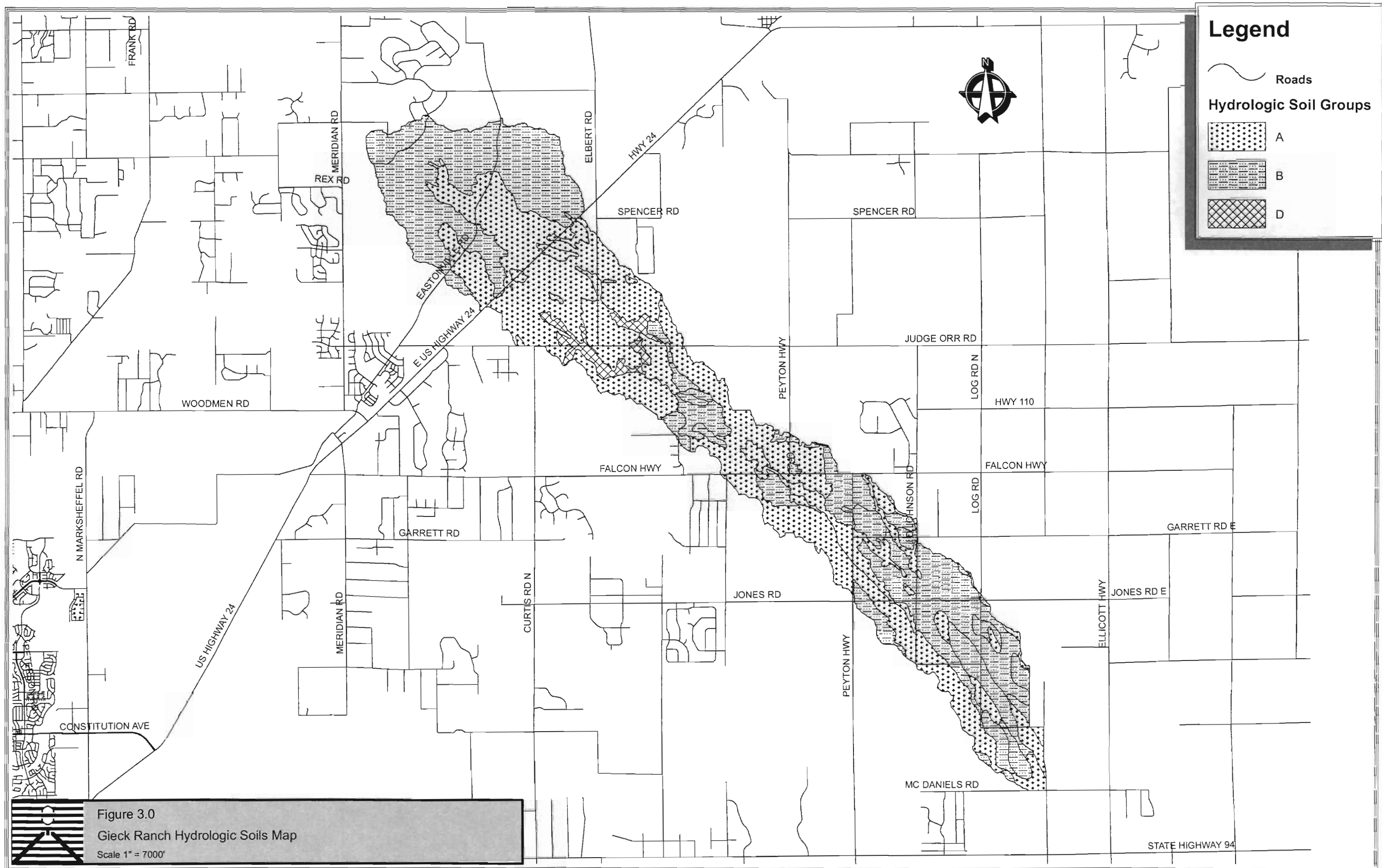
D. Existing and Future Land Uses

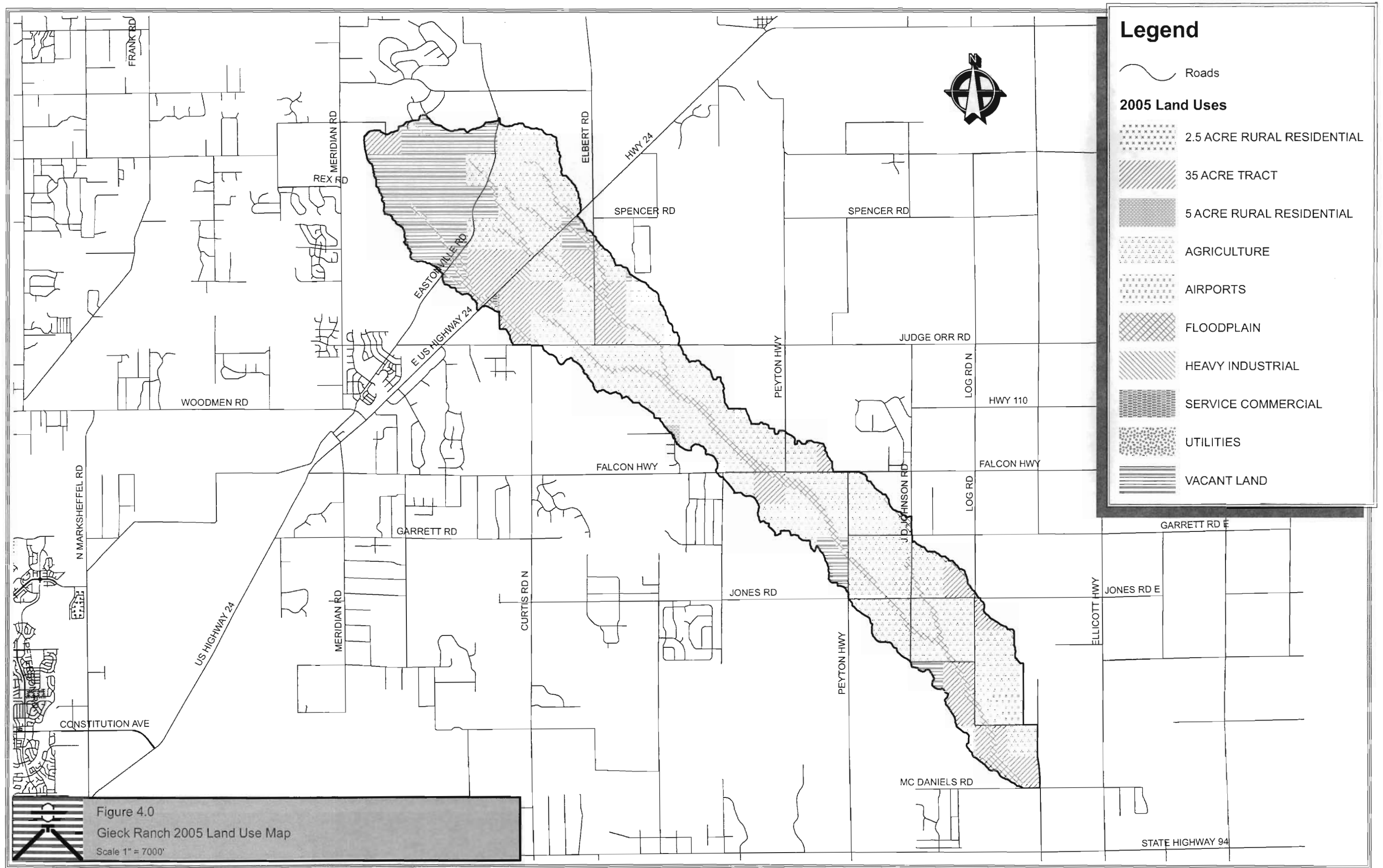
Undeveloped land within the basin is primarily rolling ranch land with some riparian areas along the Gieck Ranch drainageway and its major tributaries. The entire basin is relatively undeveloped; however it is located adjacent to rapidly developing areas. The growth rate of Colorado Springs has been among the highest in the nation since 1970, and development is continuing at a relatively high rate. Most of the residential development is northeast and east of Colorado Springs, approaching the Gieck Ranch Basin. There are several large mixed use developments planned or under way within the basin boundaries. These include Santa Fe Springs, Meridian Ranch, and Four Way Ranch.

Land use for existing conditions was based on a combination of existing land use information found in the County’s 2005 GIS dataset, field investigations, and aerial photographs. The existing land use data shown in Figure 4.0 was mapped using ArcGIS computer software. More detailed existing land use maps are provided in Figures 4.1, 4.2, and 4.3 which are located in Volume 2 of this report.

Several sources were used to determine future land use within the Gieck Ranch Drainage Basin. A base land use map was created in ArcGIS using data from “*El Paso County Future Land Use and Buildout, 2030*”, obtained from El Paso County Information Technologies. The base map was then revised to include proposed land uses from “*The Master Development Drainage Plan and Preliminary Drainage Report for Four Way Ranch*”, revised June 2004, “*The Master Development Drainage Plan, Meridian Ranch*”, dated August 21, 2001, “*Santa Fe Springs Sketch Plan*”, Dated August 8, 2004. Figure 5.0 shows the composite future conditions land use map. More detailed existing land use maps are provided in Figures 5.1, 5.2, and 5.3 which are located in Volume 2 of this report.

Land use information was used in the hydrologic analysis to determine runoff within the basin. The information will also be used in the planning of channel improvements to mitigate the anticipated increases in runoff due to development. The land use information provided in this report was based on available information and is not intended to reflect the future zoning or land use policies of El Paso County.





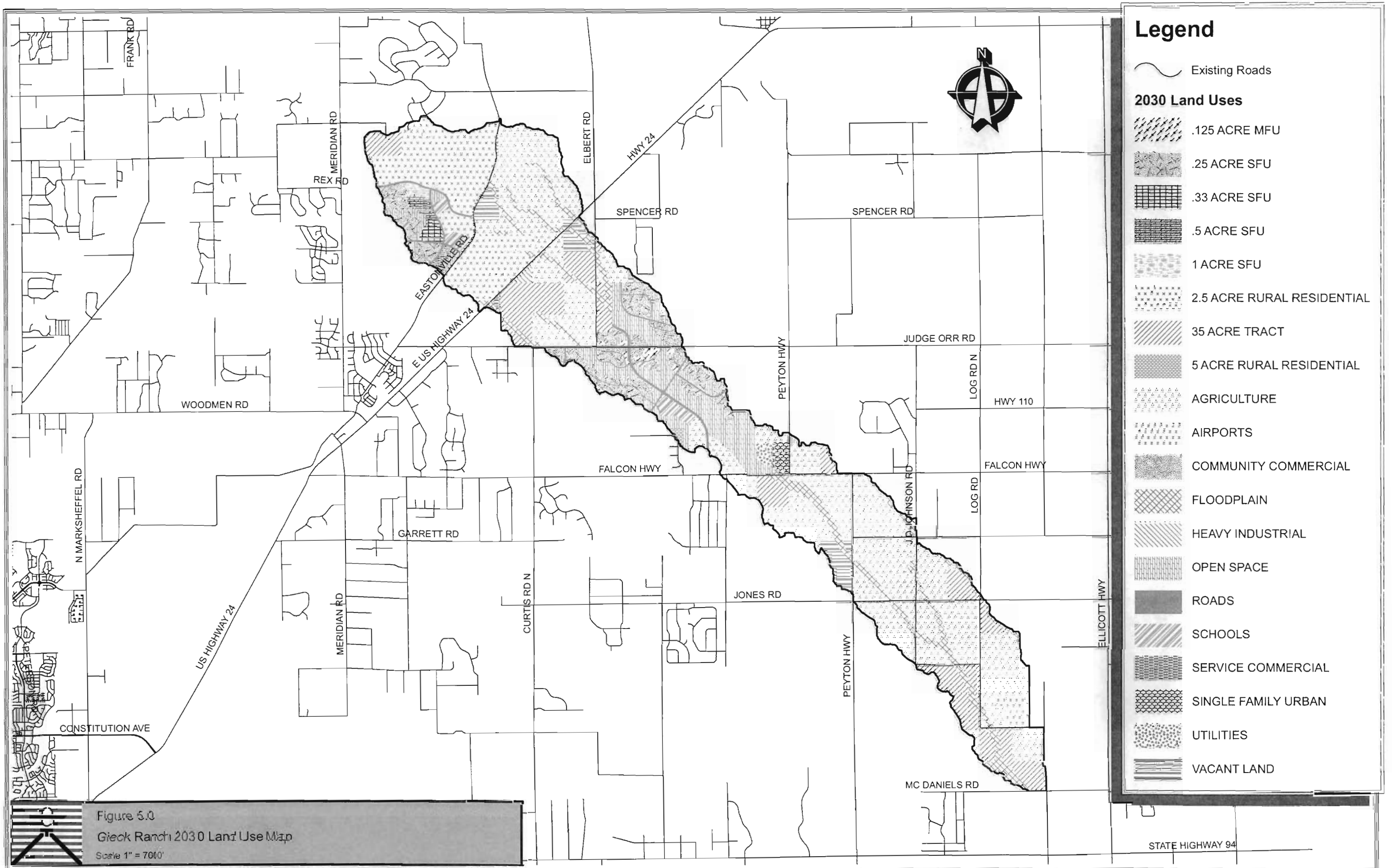


Figure 5.0
Gieck Ranch 2030 Land Use Map
Scale 1" = 7000'

III. Hydrology

A. Introduction

This section summarizes the hydrologic analysis of the Gieck Ranch Drainage Basin. Both existing conditions and future development were considered in the development of peak discharge rates and runoff volumes for the 2-, 5-, 10- and 100-year storm events. The following sections describe the data, methodologies, assumptions, and calculation methods used.

B. Hydrologic Modeling

A hydrologic model was utilized to simulate stormwater runoff in the Gieck Ranch Basin. The model was developed using the U. S. Army Corps of Engineers’ HEC-HMS hydrologic modeling program, version 3.3. The use of this model is made in compliance with the El Paso County Drainage Criteria Manual (DCM).

Delineation of the Gieck Ranch Basin and its sub-basins was performed using the El Paso County 2002 LIDAR Terrain Points data set. This data set shows the bare earth and canopy LIDAR points that were flown for a set section during April and May of 2002. The horizontal datum used for the data set is the North American Datum of 1983 and the vertical datum used is NAVD 88. The grid coordinate system used is the Colorado State Plane Coordinate System, Zone 502. The geographic locations have an absolute horizontal accuracy of 15 cm (approximately 0.5 feet) and an absolute vertical accuracy of 30 cm (approximately 1.0 feet). Additional metadata information for the data set is provided in Section 2 of the Technical Addenda.

The LIDAR data was processed using ArcGIS 9.1 computer software to create 2-foot contour intervals over the entire basin. The LIDAR data is considered by the El Paso County IT Department to be limited in it’s accuracy for creating 5 foot contours. The 2 foot contours used throughout this study were accepted because significant 2 foot contour mapping had been done from another source and was available to confirm the reliability of the LIDAR based 2-foot contours. The topographic mapping was supplemented with field observations and measurements to assist in delineating sub-basins. The Gieck Ranch Basin was initially subdivided into six major watersheds or drainageways associated with the

main stem channel and its’ five major tributaries. Minor tributaries to these major drainageways were also identified to further delineate sub-basins. A total of 91 sub-basins ranging in size from 19 to 365 acres were delineated. The sub-basins are labeled in reference to its’ associated drainageway or tributary as follows:

<u>Drainageway/Tributary</u>	<u>Basins</u>
Main Stem	MS-B1 through MS-B35
Main Stem Tributary #1	MST1-B1
Main Stem Tributary #2	MST2-B1 through MST2-B3
Main Stem Tributary #3	MST3-B1 through MST3-B2
Main Stem Tributary #4	MST4-B1 through MST4-B2
Main Stem Tributary #5	MST5-B1 through MST5-B2
Haegler Diversion	HD-B1 through HD-B6
West Fork	WF-B1 through WF-B11
West Fork Tributary #1	WFT1-B1 through WFT1-B2
East Fork	EF-B1 through EF-B8
East Fork Tributary #1	EFT1-B1 through EFT1-B4
South Fork	SF-B1 through SF-B7
South Fork Tributary #1	SFT1-B1
Southeast Fork	SE-B1 through SE-B7

Figures 6.1, 6.2 and 6.3, located in Volume 2 of this report, show the contour intervals and the sub-basin delineations for the existing and future conditions models.

C. Time of Concentration Calculations

The topographic mapping was also used to determine the longest flow path within each basin, establish elevations at the beginning and end of flow paths, and determine channel geometry within reaches. This information was used to assist in computing the time of concentration of each sub-basin and ultimately the lag time used in the hydrology model. The time of concentration was determined using the methods presented in the SCS procedure in the Technical Release Manual titled Urban Hydrology for Small Watersheds, 2nd Edition, revised June 1986 (herein referred to as TR-55) and is calculated as the sum of the sheet flow, shallow concentrated flow, and open channel flow. For the existing conditions

model time of concentration calculations, sheet flow was limited to a maximum of 300 feet and shallow concentrated flow was limited to a maximum of 2,000 feet. Open channel flow characteristics were determined using an iterative process whereas an initial depth was determined for each reach using Haestad Methods' Flowmaster computer program. The depth was calculated based on channel geometry and characteristics and an assumed flow. A roughness coefficient of 0.070 was used for channels with mild grassy side slopes and wide channel bottoms and a coefficient of 0.050 was used for narrow channels with steeper earthen side slopes. The open channel flow travel time was then calculated and the resulting lag time was used in a preliminary HEC-HMS model run. The resulting flows for the 2-year return period storm were then used to re-calculate the channel flow depths, the open channel flow travel times and the sub-basin lag times that were used in the final HMS runoff model runs. The existing conditions time of concentration calculations and documentation are provided in Section 3 of the Technical Addenda.

For the future conditions model time of concentration calculations each sub-basin was classified as urban, mixed or rural depending on the amount of proposed development that is to occur by the year 2030. Sheet flow was limited to a maximum of 50 feet for urban sub-basins and 150 feet for mixed sub-basins. Shallow concentrated flow was limited to a maximum of 250 feet for urban sub-basins and 500 feet for mixed sub-basins. The open channel reach lengths for urban and mixed sub-basins were adjusted for the shorter sheet flow and shallow concentrated flow lengths. The open channel geometries and roughness coefficients were also revised to reflect conditions representing man-made channels. The flow lengths and channel conditions were not adjusted for rural basins. Open channel flow characteristics were determined using an iterative process similar to that for the existing conditions. The future conditions time of concentration calculations and documentation are provided in Section 4 of the Technical Addenda.

D. Runoff Curve Numbers

Composite runoff curve numbers were generated using methods presented in TR-55 and the ArcGIS computer program. From the land use information and the soils mapping data, the area of each land-use/soil group combination present within each sub-basin was determined using the ArcGIS program. Next, a curve number (CN) was assigned to each land-use/soil type combination. The curve numbers

used were calculated based on the percent imperviousness assigned to each land use category. Table 1.0 shows a summary of land use data, the percent imperviousness assigned to each land use category and the resultant curve numbers for the existing and future conditions.

Finally, an area weighted Composite Curve Number (CCN) for each sub-basin was calculated based on the area and curve number of each land-use/soil combination present in the sub-basin. Work sheets used in the calculation of the composite curve numbers are included in Sections 5 and 6 of the Technical Addenda. A summary of sub-basin characteristics used in the HEC-HMS runoff model is provided in Table 2.0 for the existing conditions and in Table 3.0 for the future conditions.

Table 1.0: Land Use Data and Curve Number Calculations

Existing Land Uses

Land Use	Area (acres)	% of Total Area	Average % Impervious Area	Cover Condition	Use HSG B for regraded HSG A?	Composite Curve Number (CCN)			
						Hydrologic Soil Group			
						A	B	C	D
Agriculture (Rangeland)	7817	55.4%	0%	Fair	No	58	73	82	86
Vacant Land (Rangeland)	2249	15.9%	0%	Fair	No	58	73	82	86
Exclusion (Floodplain Rangeland and Roads)	1669	11.8%	0.5%	Fair	No	58	73	82	86
35 Acre Tract	2147	15.2%	2%	Fair	No	59	74	82	86
5 Acre Rural Residential	32	0.2%	5%	Fair	No	60	74	83	87
2.5 Acre Rural Residential	12	0.1%	12%	Fair	No	63	76	84	87
Airports	135	1.0%	5%	Fair	Yes	60	74	83	87
Service Commercial	16	0.1%	85%	Good	Yes	89	92	94	95
Heavy Industrial	35	0.2%	72%	Good	Yes	81	88	91	93
Utilities	0.2	0.0%	60%	Good	Yes	74	83	88	91
	14111	100%							

Future Land Uses

Land Use	Area (acres)	% of Total Area	Average % Impervious Area	Cover Condition	Use HSG B for regraded	Composite Curve Number (CCN)			
						Hydrologic Soil Group			
						A	B	C	D
Agriculture (Rangeland)	5767	40.9%	0%	Fair	No	58	73	82	86
Vacant Land (Rangeland)	443	3.1%	0%	Fair	No	58	73	82	86
Exclusion (Floodplain Rangeland and Roads)	1249	8.8%	0.5%	Fair	No	58	73	82	86
Open Space (Rangeland)	1299	9.2%	0%	Fair	No	58	73	82	86
35 Acre Tract	1703	12.1%	2%	Fair	No	59	74	82	86
5 Acre Rural Residential	34	0.2%	5%	Fair	No	60	74	83	87
2.5 Acre Rural Residential	1535	10.9%	12%	Fair	No	63	76	84	87
1 Acre Single Family Urban	40	0.3%	20%	Fair	No	66	78	85	88
1/2 Acre Single Family Urban	64	0.5%	25%	Good	Yes	54	70	80	85
1/3 Acre Single Family Urban	62	0.4%	30%	Good	Yes	57	72	81	85
1/4 Acre Single Family Urban	890	6.3%	38%	Good	Yes	61	75	83	87
1/8 Acre Single Family Urban	9	0.1%	65%	Good	Yes	77	85	90	92
1/8 Acre Multifamily Urban	58	0.4%	65%	Good	Yes	77	85	90	92
Single Family Urban (1/4 acre avg.)	87	0.6%	38%	Good	Yes	61	75	83	87
Schools	173	1.2%	65%	Good	Yes	77	85	90	92
Roads-paved, curb and storm sewer	280	2.0%	100%	N/A	Yes	98	98	98	98
Airports	135	1.0%	5%	Fair	Yes	60	74	83	87
Service Commercial	77	0.5%	85%	Good	Yes	89	92	94	95
Community Commercial	122	0.9%	85%	Good	Yes	89	92	94	95
Heavy Industrial	35	0.2%	72%	Good	Yes	81	88	91	93
Utilities	51	0.4%	60%	Good	Yes	74	83	88	91
	14111	100.0%							

Notes:

- Composite Curve Numbers were calculated using CN = 98 for impervious areas and CN = 58, 73, 82, and 86 for soil types A, B, C, and D with pervious areas in fair condition and CN = 39, 61, 74, 80 with pervious areas in good condition. Good condition was used for existing urban areas which are assumed to be landscaped or proposed urban areas anticipated to be landscaped.
- For regraded areas with HSG A, the CCN for HSG B was used to calculate the overall Basin CN as indicated.

Basin ID	Basin Area (acres)	Basin Area (sq. miles)	Basin CCN	tlag (mins)	Average % Imp. Area	Impervious Acres
MS-B1	174.5	0.2727	74	20	1.3%	2.3
MS-B2	52.6	0.0821	73	34	0.0%	0.0
MS-B3	121.5	0.1898	72	32	0.2%	0.3
MS-B4	114.7	0.1792	69	91	0.1%	0.2
MS-B5	205.7	0.3214	64	43	0.0%	0.0
MS-B6	110.0	0.1720	59	103	0.2%	0.2
MS-B7	29.2	0.0456	58	51	0.5%	0.1
MS-B8	100.6	0.1571	58	129	0.6%	0.6
MS-B9	139.7	0.2183	58	179	0.2%	0.3
MS-B10	115.0	0.1797	58	157	0.5%	0.5
MS-B11	316.1	0.4939	66	69	1.1%	3.4
MS-B12	291.1	0.4548	59	285	0.3%	0.8
MS-B13	90.6	0.1415	60	72	0.1%	0.1
MS-B14	61.9	0.0966	60	38	0.1%	0.0
MS-B15	140.0	0.2187	70	81	0.3%	0.5
MS-B16	150.7	0.2354	59	76	0.1%	0.2
MS-B17	202.0	0.3156	58	185	0.1%	0.2
MS-B18	132.7	0.2073	60	79	0.0%	0.0
MS-B19	54.1	0.0845	62	65	0.1%	0.1
MS-B20	82.7	0.1292	64	61	0.5%	0.4
MS-B21	246.4	0.3850	63	164	0.8%	1.9
MS-B22	212.0	0.3312	62	81	0.7%	1.4
MS-B23	207.2	0.3237	58	167	0.0%	0.1
MS-B24	292.8	0.4576	58	72	0.1%	0.2
MS-B25	331.3	0.5176	65	73	0.1%	0.3
MS-B26	118.4	0.1850	61	83	0.1%	0.2
MS-B27	344.8	0.5388	65	128	0.0%	0.1
MS-B28	59.1	0.0924	68	52	0.3%	0.2
MS-B29	198.9	0.3108	62	83	1.1%	2.1
MS-B30	48.3	0.0754	69	78	1.8%	0.9
MS-B31	192.0	0.2999	61	240	1.4%	2.6
MS-B32	87.7	0.1371	64	81	0.3%	0.2
MS-B33	93.6	0.1462	68	57	1.3%	1.2
MS-B34	44.5	0.0696	74	61	1.9%	0.9
MS-B35	75.6	0.1181	67	48	1.1%	0.9
MST1-B1	156.3	0.2442	70	58	0.6%	1.0
MST2-B1	132.8	0.2076	73	43	0.2%	0.3
MST2-B2	262.9	0.4108	70	44	0.0%	0.1
MST2-B3	213.1	0.3329	58	118	0.1%	0.2
MST3-B1	75.7	0.1183	58	124	0.0%	0.0
MST3-B2	178.2	0.2784	59	179	1.3%	2.2
MST4-B1	274.0	0.4281	64	70	0.5%	1.3
MST4-B2	116.9	0.1827	69	53	0.0%	0.0
MST5-B1	165.0	0.2578	64	51	0.0%	0.0
MST5-B2	225.4	0.3522	61	138	0.0%	0.1
HD-B1	264.3	0.4129	73	50	0.0%	0.1

Basin ID	Basin Area (acres)	Basin Area (sq. miles)	Basin CCN	tlag (mins)	Average % Imp. Area	Impervious Acres
HD-B2	261.3	0.4082	70	48	0.1%	0.1
HD-B3	101.0	0.1578	64	48	0.3%	0.3
HD-B4	117.9	0.1843	61	65	1.5%	1.7
HD-B5	100.7	0.1573	62	165	10.8%	10.9
HD-B6	165.1	0.2580	64	71	0.5%	0.9
WF-B1	115.1	0.1799	72	54	0.0%	0.0
WF-B2	77.6	0.1212	67	38	0.0%	0.0
WF-B3	18.6	0.0291	73	24	0.0%	0.0
WF-B4	61.7	0.0964	66	32	1.1%	0.7
WF-B5	101.8	0.1590	68	37	2.0%	2.0
WF-B6	188.8	0.2950	63	81	3.8%	7.2
WF-B7	59.9	0.0935	61	142	1.3%	0.8
WF-B8	116.5	0.1820	61	71	0.0%	0.0
WF-B9	209.2	0.3268	68	66	0.1%	0.2
WF-B10	74.0	0.1156	62	200	1.5%	1.1
WF-B11	365.2	0.5707	64	56	0.1%	0.3
WFT1-B1	196.5	0.3071	65	87	1.2%	2.4
WFT1-B2	167.1	0.2610	66	86	16.1%	26.9
EF-B1	68.8	0.1076	73	20	0.0%	0.0
EF-B2	79.9	0.1248	73	26	0.0%	0.0
EF-B3	210.5	0.3289	73	26	0.0%	0.0
EF-B4	351.9	0.5498	73	34	0.0%	0.2
EF-B5	85.1	0.1329	73	42	0.1%	0.1
EF-B6	25.5	0.0398	58	61	0.3%	0.1
EF-B7	70.9	0.1107	58	66	0.3%	0.2
EF-B8	115.7	0.1807	58	119	0.7%	0.8
EFT1-B1	64.2	0.1004	73	27	0.0%	0.0
EFT1-B2	80.7	0.1261	68	28	0.0%	0.0
EFT1-B3	253.0	0.3953	67	70	0.1%	0.2
EFT1-B4	30.0	0.0470	59	74	0.3%	0.1
SF-B1	127.7	0.1995	64	55	0.5%	0.7
SF-B2	223.9	0.3498	70	61	0.0%	0.0
SF-B3	76.9	0.1202	70	60	0.0%	0.0
SF-B4	181.4	0.2835	67	109	0.1%	0.2
SF-B5	241.1	0.3767	67	101	0.0%	0.1
SF-B6	89.8	0.1403	72	48	0.1%	0.1
SF-B7	140.7	0.2199	69	67	0.1%	0.2
SFT1-B1	233.4	0.3647	69	74	0.0%	0.0
SE-B1	297.5	0.4649	73	39	0.8%	2.5
SE-B2	325.5	0.5087	72	94	0.0%	0.1
SE-B3	47.4	0.0741	72	102	2.0%	0.9
SE-B4	152.3	0.2380	73	68	0.1%	0.2
SE-B5	317.7	0.4964	71	204	0.4%	1.2
SE-B6	167.3	0.2614	73	99	3.6%	6.0
SE-B7	252.2	0.3940	63	83	0.8%	2.0
Totals	14111	22.05	66		0.7%	100

Basin ID	Basin Area (acres)	Basin Area (sq. miles)	Basin CCN	tflag (mins)	Average % Imp. Area	Impervious Acres
MS-B1	174.5	0.2727	75	16	6.7%	11.7
MS-B2	52.6	0.0821	78	25	19.4%	10.2
MS-B3	121.5	0.1898	76	27	15.3%	18.6
MS-B4	114.7	0.1792	74	37	15.1%	17.3
MS-B5	207.4	0.3240	72	19	24.1%	50.1
MS-B6	110.0	0.1720	61	82	5.7%	6.2
MS-B7	29.2	0.0456	60	38	5.3%	1.6
MS-B8	100.6	0.1571	58	129	0.6%	0.6
MS-B9	139.7	0.2183	58	179	0.2%	0.3
MS-B10	115.0	0.1797	58	157	0.5%	0.5
MS-B11	316.1	0.4939	72	27	16.1%	51.0
MS-B12	291.2	0.4550	68	52	21.8%	63.5
MS-B13	90.6	0.1415	71	27	28.5%	25.8
MS-B14	61.9	0.0967	80	14	49.9%	30.9
MS-B15	140.0	0.2187	74	60	12.6%	17.6
MS-B16	150.7	0.2354	60	63	0.9%	1.3
MS-B17	202.0	0.3156	63	56	10.6%	21.4
MS-B18	132.7	0.2073	70	24	21.4%	28.4
MS-B19	54.1	0.0845	75	22	25.4%	13.7
MS-B20	82.7	0.1292	64	61	1.4%	1.2
MS-B21	246.4	0.3850	63	164	0.8%	1.9
MS-B22	212.0	0.3312	62	81	0.7%	1.4
MS-B23	207.2	0.3237	58	167	0.0%	0.1
MS-B24	292.8	0.4576	58	72	0.1%	0.2
MS-B25	331.3	0.5176	65	73	0.1%	0.3
MS-B26	118.4	0.1850	61	79	0.1%	0.2
MS-B27	344.8	0.5388	65	128	0.0%	0.1
MS-B28	59.1	0.0924	68	52	0.3%	0.2
MS-B29	198.9	0.3108	63	78	1.7%	3.5
MS-B30	48.3	0.0754	69	78	1.8%	0.9
MS-B31	192.0	0.2999	61	240	1.4%	2.6
MS-B32	87.7	0.1371	64	81	0.3%	0.2
MS-B33	93.6	0.1462	68	57	1.3%	1.2
MS-B34	44.5	0.0696	74	61	1.9%	0.9
MS-B35	75.6	0.1181	67	48	1.1%	0.9
MST1-B1	156.3	0.2442	73	37	11.9%	18.6
MST2-B1	132.8	0.2076	76	22	11.7%	15.6
MST2-B2	261.3	0.4082	73	27	11.9%	31.0
MST2-B3	213.1	0.3329	58	97	1.0%	2.0
MST3-B1	80.0	0.1249	59	79	1.6%	1.3
MST3-B2	173.9	0.2718	59	179	1.3%	2.2
MST4-B1	274.0	0.4281	75	23	28.3%	77.5
MST4-B2	116.9	0.1827	73	29	13.2%	15.4
MST5-B1	165.0	0.2578	77	22	37.6%	62.1
MST5-B2	225.4	0.3522	69	60	17.5%	39.5
HD-B1	264.3	0.4129	75	23	29.6%	78.2

Basin ID	Basin Area (acres)	Basin Area (sq. miles)	Basin CCN	tflag (mins)	Average % Imp. Area	Impervious Acres
HD-B2	261.3	0.4082	79	17	45.6%	119.1
HD-B3	101.0	0.1578	68	27	12.0%	12.1
HD-B4	117.9	0.1843	64	41	11.0%	12.9
HD-B5	100.7	0.1573	64	73	14.2%	14.3
HD-B6	165.1	0.2580	66	41	6.1%	10.1
WF-B1	115.1	0.1799	74	26	26.7%	30.7
WF-B2	77.6	0.1212	81	16	47.2%	36.6
WF-B3	14.4	0.0224	82	13	36.6%	5.3
WF-B4	61.7	0.0964	69	20	12.0%	7.4
WF-B5	101.8	0.1590	71	29	11.8%	12.0
WF-B6	188.8	0.2950	63	76	3.8%	7.2
WF-B7	59.9	0.0935	61	122	1.3%	0.8
WF-B8	116.5	0.1820	62	67	2.7%	3.1
WF-B9	209.2	0.3268	82	27	40.8%	85.3
WF-B10	74.0	0.1156	79	28	48.7%	36.0
WF-B11	365.2	0.5707	78	27	37.6%	137.4
WFT1-B1	200.8	0.3137	69	36	11.8%	23.7
WFT1-B2	167.1	0.2610	66	48	16.1%	26.9
EF-B1	70.5	0.1102	76	15	11.3%	8.0
EF-B2	79.9	0.1248	73	26	0.0%	0.0
EF-B3	210.5	0.3289	73	26	0.0%	0.0
EF-B4	351.9	0.5498	73	34	0.0%	0.2
EF-B5	85.1	0.1329	73	42	0.1%	0.1
EF-B6	25.5	0.0398	58	61	0.3%	0.1
EF-B7	70.9	0.1107	58	66	0.3%	0.2
EF-B8	115.7	0.1807	58	119	0.7%	0.8
EFT1-B1	62.6	0.0978	76	20	11.9%	7.5
EFT1-B2	80.7	0.1261	68	28	0.0%	0.0
EFT1-B3	253.0	0.3953	67	70	0.1%	0.2
EFT1-B4	30.0	0.0470	59	74	0.3%	0.1
SF-B1	127.7	0.1995	64	53	1.4%	1.8
SF-B2	223.9	0.3498	70	61	0.0%	0.0
SF-B3	76.9	0.1202	70	60	0.0%	0.0
SF-B4	181.4	0.2835	67	109	0.1%	0.2
SF-B5	241.1	0.3767	67	101	0.0%	0.1
SF-B6	89.8	0.1403	72	55	0.1%	0.1
SF-B7	140.7	0.2199	69	67	0.1%	0.2
SFT1-B1	233.4	0.3647	69	73	0.0%	0.0
SE-B1	297.5	0.4649	73	39	0.8%	2.5
SE-B2	325.5	0.5087	72	94	0.0%	0.1
SE-B3	47.4	0.0741	72	102	2.0%	0.9
SE-B4	152.3	0.2380	73	68	0.1%	0.2
SE-B5	317.7	0.4964	71	204	0.4%	1.2
SE-B6	167.3	0.2614	73	99	3.6%	6.0
SE-B7	252.2	0.3940	63	85	0.8%	2.0
Totals	14111	22.05	69		9.5%	1343

E. Design Storm Events

Design storm rainfall amounts for HEC-HMS modeling were derived from the U.S. Department of Commerce, NOAA, Precipitation-Frequency Atlas of the Western United States. Information was determined for the Colorado Springs area for the 2-, 5-, 10-, and 100-year, 24-hour storm events. Rainfall amounts for representative storm events were determined to be 2.15 inches for the 2-year event, 2.7 inches for the 5-year event, 3.3 inches for the 10-year event, and 4.5 inches for the 100-year event. In accordance with the Colorado Springs/El Paso County Drainage Criteria Manual standards, a Type II-A storm with an antecedent moisture condition of II was applied to the hydrologic modeling. Because HEC-HMS does not contain an option for the selection of a Type II-A storm distribution, the distribution was developed separately and entered directly into HEC-HMS via the precipitation gage input options. The Type IIA cumulative rainfall distribution and the HEC-HMS cumulative rainfall input values for the four return periods are shown in Section 7 of the Technical Addenda.

Normally an areal reduction factor is applied to the rainfall depths for drainage basins greater than 10 square miles per the NOAA Atlas 2. This factor accounts for the variability in the rainfall depth over the entire basin and is useful in estimating the total runoff from the basin. This adjustment only technically applies to flows in the main stem where the drainage area exceeds 10 square miles. Since many of the structures to be evaluated for deficiencies are located outside this area, it is appropriate to not reduce the flows across the entire basin. Therefore, an areal reduction factor was not used in the modeling of this drainage basin. The net result is that flows are approximately 3% higher than if a reduction factor would have been used.

F. Unit Hydrograph

The SCS unit hydrograph method was used to develop the outflow hydrographs for each of the sub-basins. Development of unit hydrographs requires the development of the lag time for each of the sub-basins. Lag times were determined from the time of concentration in accordance with the SCS National Engineering Handbook. The lag time for each sub-basin was computed as 60% of time of concentration. The computed lag times are shown in Tables 2.0 and 3.0 above.

G. Channel Routing

Channel routing and attenuation within the stream reach was performed using the Kinematic Wave method for hydrologic river routing. The Kinematic Wave method requires input parameters of channel slope, Manning's roughness coefficient, channel geometry, and channel length. Tables 4.0 and 5.0 show the channel reach input data used in the hydrologic modeling. The HEC-HMS computer program was used to create a watershed model with basins, reaches and junctions to simulate the physical characteristics of the watershed. Labeling of the junctions and reaches was done similarly to the sub-basin labeling convention using J for junctions and R for reaches (i.e. MS-J1 for Main Stem Junction # 1 and MS-R1 for Main Stem Reach #1). Figures 7.1, 7.2, and 7.3, located in Volume 2 of this report, show the model schematic diagram. Runoff volumes from each of the sub-basins were combined at channel nodes and routed through channel reaches to estimate runoff throughout the basin.

Reach ID	Reach Length R (ft)	Reach Slope (%)	Mannings n value	Reach Side Slope (h/v)	Bottom Width B (ft)
MS-R1	2400	1.67%	0.05	7	20
MS-R2	1800	2.22%	0.05	5	15
MS-R3	1270	2.05%	0.07	10	50
MS-R4	2900	1.79%	0.07	10	25
MS-R5	6040	1.79%	0.05	8	20
MS-R6	1050	1.24%	0.07	15	20
MS-R7	6190	1.86%	0.05	6	25
MS-R8	1870	1.60%	0.07	15	20
MS-R9	450	2.67%	0.07	20	40
MS-R10	1580	1.71%	0.07	50	65
MS-R11	5400	1.48%	0.07	15	45
MS-R12	570	1.05%	0.05	4	30
MS-R13	3110	1.09%	0.05	6	40
MS-R14	7160	1.12%	0.05	7	25
MS-R15	3400	1.03%	0.05	6	45
MS-R16	2400	1.13%	0.05	6	30
MS-R17	630	0.79%	0.05	7	25
MS-R18	5140	0.88%	0.05	5	25
MS-R18A	3456	1.59%	0.07	60	80
MS-R19	1640	0.91%	0.05	8	30
MS-R20	2670	1.01%	0.07	15	50
MS-R21	5760	1.04%	0.05	8	40
MS-R22	3410	1.17%	0.07	10	25
MS-R23	3240	0.93%	0.05	8	15
MS-R24	1660	1.02%	0.07	40	30
MS-R25	3930	1.07%	0.07	10	15
MS-R26	760	0.66%	0.07	12	25
MS-R27	1570	1.59%	0.07	12	25
MS-R28	3730	0.88%	0.07	15	60
MS-R29	580	0.86%	0.07	25	40
MS-R30	2220	1.13%	0.07	100	80
MST2-R1	4010	2.00%	0.07	12	25
MST2-R2	6450	1.94%	0.07	10	25
MST3-R1	5970	1.76%	0.07	60	70
MST4-R1	3390	1.30%	0.07	25	45
MST5-R1	7230	1.08%	0.05	6	30
HD-R1	2900	2.07%	0.07	40	60
HD-R2	2650	2.08%	0.07	20	30
HD-R3	2460	1.22%	0.05	8	20
HD-R4	5920	1.52%	0.07	50	80
HD-R5	3730	1.61%	0.05	9	10
WF-R1	2210	1.72%	0.07	15	25
WF-R2	2200	2.27%	0.07	40	50
WF-R3	3200	1.69%	0.05	6	15
WF-R4	6270	1.82%	0.07	15	30
WF-R5	1130	1.24%	0.07	10	30
WF-R6	1060	1.42%	0.07	20	25

Reach ID	Reach Length R (ft)	Reach Slope (%)	Mannings n value	Reach Side Slope (h/v)	Bottom Width B (ft)
WF-R7	3600	1.19%	0.07	15	35
WF-R8	5900	1.24%	0.05	8	25
WFT1-R1	6040	1.84%	0.07	15	45
EF-R1	2660	2.26%	0.05	8	20
EF-R2	2510	2.19%	0.05	7	30
EF-R3	4770	1.47%	0.05	7	20
EF-R4	1130	1.42%	0.05	7	30
EF-R5	2160	1.76%	0.05	4	10
EF-R6	1440	1.25%	0.05	7	15
EF-R7	5330	1.31%	0.05	6	15
EFT1-R1	3230	2.11%	0.07	15	30
EFT1-R2	6820	1.64%	0.07	25	35
EFT1-R3	2260	1.99%	0.07	10	25
SF-R1	6120	1.27%	0.07	70	50
SF-R2	3840	1.17%	0.07	30	35
SF-R3	2740	0.95%	0.05	7	60
SF-R4	1560	0.51%	0.07	10	40
SF-R5	2720	0.81%	0.07	12	30
SF-R6	4450	0.94%	0.07	20	30
SE-R1	5690	1.05%	0.07	60	60
SE-R2	3010	1.10%	0.07	50	120
SE-R3	6750	0.81%	0.07	75	100
SET1-R1	5580	0.99%	0.07	80	80
SET1-R2	3650	0.96%	0.07	100	30

Reach ID	Reach Length R (ft)	Reach Slope (%)	Mannings n value	Reach Side Slope (h/v)	Bottom Width B (ft)
MS-R1	2400	1.67%	0.05	8	20
MS-R2	1800	2.22%	0.05	8	20
MS-R3	1270	2.05%	0.05	8	20
MS-R4	2900	1.79%	0.05	4	15
MS-R5	6040	1.79%	0.05	8	20
MS-R6	1050	1.24%	0.05	8	20
MS-R7	6190	1.86%	0.05	6	25
MS-R8	1870	1.60%	0.07	15	20
MS-R9	450	2.67%	0.07	20	40
MS-R10	1580	1.71%	0.07	50	65
MS-R11	5400	1.48%	0.05	4	15
MS-R12	570	1.05%	0.05	4	15
MS-R13	3110	1.09%	0.05	4	15
MS-R14	7160	1.12%	0.05	8	20
MS-R15	3400	1.03%	0.05	8	20
MS-R16	2400	1.13%	0.05	4	15
MS-R17	630	0.79%	0.05	4	15
MS-R18	5140	0.88%	0.05	5	25
MS-R18A	3456	1.59%	0.07	80	60
MS-R19	1640	0.91%	0.05	8	30
MS-R20	2670	1.01%	0.07	15	50
MS-R21	5760	1.04%	0.05	8	40
MS-R22	3410	1.17%	0.07	10	25
MS-R23	3240	0.93%	0.05	8	15
MS-R24	1660	1.02%	0.07	40	30
MS-R25	3930	1.07%	0.07	10	15
MS-R26	760	0.66%	0.07	12	25
MS-R27	1570	1.59%	0.07	12	25
MS-R28	3730	0.88%	0.07	15	60
MS-R29	580	0.86%	0.07	25	40
MS-R30	2220	1.13%	0.05	8	20
MST2-R1	4010	2.00%	0.05	8	20
MST2-R2	6450	1.94%	0.05	8	20
MST3-R1	5970	1.76%	0.07	60	70
MST4-R1	3390	1.30%	0.05	8	20
MST5-R1	7230	1.08%	0.05	4	15
HD-R1	2900	2.07%	0.05	4	15
HD-R2	2650	2.08%	0.05	8	20
HD-R3	2460	1.22%	0.05	8	20
HD-R4	5920	1.52%	0.05	8	20
HD-R5	3730	1.61%	0.05	4	15
WF-R1	2210	1.72%	0.05	4	15
WF-R2	2200	2.27%	0.05	8	20
WF-R3	3200	1.69%	0.05	8	20
WF-R4	6270	1.82%	0.07	15	30
WF-R5	1130	1.24%	0.07	10	30
WF-R6	1060	1.42%	0.05	8	20

Reach ID	Reach Length R (ft)	Reach Slope (%)	Mannings n value	Reach Side Slope (h/v)	Bottom Width B (ft)
WF-R7	3600	1.19%	0.05	4	15
WF-R8	5900	1.24%	0.05	4	15
WFT1-R1	6040	1.84%	0.05	8	20
EF-R1	2660	2.26%	0.05	8	20
EF-R2	2510	2.19%	0.05	7	30
EF-R3	4770	1.47%	0.05	7	20
EF-R4	1130	1.42%	0.05	7	30
EF-R5	2160	1.76%	0.05	4	10
EF-R6	1440	1.25%	0.05	7	15
EF-R7	5330	1.31%	0.05	6	15
EFT1-R1	3230	2.11%	0.07	15	30
EFT1-R2	6820	1.64%	0.07	25	35
EFT1-R3	2260	1.99%	0.07	10	25
SF-R1	6120	1.27%	0.07	70	50
SF-R2	3840	1.17%	0.07	30	35
SF-R3	2740	0.95%	0.05	7	60
SF-R4	1560	0.51%	0.07	10	40
SF-R5	2720	0.81%	0.07	12	30
SF-R6	4450	0.94%	0.07	20	30
SE-R1	5690	1.05%	0.07	60	60
SE-R2	3010	1.10%	0.07	50	120
SE-R3	6750	0.81%	0.07	75	100
SET1-R1	5580	0.99%	0.07	80	80
SET1-R2	3650	0.96%	0.07	100	30

H. Hydrologic Model Results

The results presented in this report are intended for major drainage facilities located within the Gieck Ranch Drainage Basin. It is not intended for small drainage facilities associated with private development. Hydrology for these areas should be performed during final design using the representative criteria outlined in the DCM manual. The results of the hydrologic modeling analysis are included in Sections 8 and 9 of the Technical Addenda for the existing conditions and future conditions, respectively. A summary of the peak flows at selected road crossings and stream confluences for the existing and future conditions is provided in Tables 6.1 through 6.4 for the 2-year, 5-year, 10-year, and 100-year storm events, respectively. Hydrographs for these selected locations are included in Sections 10 and 11 of the Technical Addenda. The Gieck Ranch Basin outfall is just downstream of McDaniels Road. The total basin discharge at the outfall was determined by summing the time-series hydrograph data for the Main Stem flow at McDaniels Road and the Southeast Fork flow at McDaniels Road. The combined outfall discharge hydrographs are included in the Technical Addenda.

Table 6.1: Summary of Flows at Selected Design Points – 2-year Storm Event

Design Point ID	Design Point Location	Hydrologic Element	Accumulative Area (mi ²)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	% Difference Peak Flow	Existing Volume (ac-ft)	Future Volume (ac-ft)	% Difference Volume
1	Haegler Diversion at Eastonville Road	HD-J2	0.8	58	192	230%	15	23	58%
2	West Fork at Eastonville Road	WF-J1	0.3	18	72	299%	5	10	81%
3	Main Channel at Eastonville Road	MS-J4	1.3	104	203	95%	20	29	43%
4	Haegler Diversion at Highway 24	HD-J4	1.3	62	205	229%	17	27	59%
5	West Fork at Highway 24	WF-J3	0.4	23	98	328%	8	14	66%
6	Main Channel at Highway 24	MS-J6	2.5	120	304	153%	33	44	34%
7	East Fork at Highway 24	EF-J4	1.2	128	160	25%	25	26	2%
8	Main Channel at Elbert Road	MS-J7	3.0	120	303	152%	34	47	36%
9	East Fork at Elbert Road	EF-J6	2.1	134	162	21%	34	35	4%
10	West Fork at Judge Orr Road	WF-J6	1.5	101	312	209%	36	56	55%
11	Confluence of East Fork and Main Channel	MS-J9	5.7	204	462	126%	69	83	20%
12	Main Channel at Judge Orr Road	MS-J11	6.7	212	486	129%	75	102	35%
13	Confluence of West Fork and Main Channel	MS-J12	11.2	260	866	233%	120	194	62%
14	Main Channel at Falcon Highway	MS-J16	13.4	273	904	231%	131	230	75%
15	Main Channel at Peyton Highway	MS-J19	15.1	279	894	220%	135	235	74%
16	Main Channel at Jones Road	MS-J20	15.6	282	890	215%	138	240	75%
17	South Fork at Jones Road	SF-J4	1.3	51	51	0%	21	21	0%
18	Confluence of South Fork and Main Channel	MS-J22	17.9	309	927	200%	162	268	65%
19	Southeast Fork at McDaniels Road	SE-J3	2.4	74	73	-1%	37	37	0%
20	Main Channel at McDaniels Road	MS-J29	19.6	317	915	188%	165	278	69%
21	Total Combined Outfall	SE-J3 plus MS-J29	22.0	367	968	164%	202	315	56%

The 2-year storm event future undetained peak flow is estimated to increase by 164% over the existing peak flow while the future volume of runoff is estimated to increase by 56%.

Table 6.2: Summary of Flows at Selected Design Points – 5-year Storm Event

Design Point ID	Design Point Location	Hydrologic Element	Accumulative Area (mi ²)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	% Difference Peak Flow	Existing Volume (ac-ft)	Future Volume (ac-ft)	% Difference Volume
1	Haegler Diversion at Eastonville Road	HD-J2	0.8	122	359	195%	26	38	43%
2	West Fork at Eastonville Road	WF-J1	0.3	39	130	235%	10	16	59%
3	Main Channel at Eastonville Road	MS-J4	1.3	214	389	82%	37	50	33%
4	Haegler Diversion at Highway 24	HD-J4	1.3	137	396	189%	31	45	43%
5	West Fork at Highway 24	WF-J3	0.4	52	186	258%	16	23	47%
6	Main Channel at Highway 24	MS-J6	2.5	262	591	126%	62	78	27%
7	East Fork at Highway 24	EF-J4	1.2	292	334	14%	44	45	2%
8	Main Channel at Elbert Road	MS-J7	3.0	262	590	126%	68	84	25%
9	East Fork at Elbert Road	EF-J6	2.1	307	344	12%	62	64	4%
10	West Fork at Judge Orr Road	WF-J6	1.5	241	634	163%	72	101	40%
11	Confluence of East Fork and Main Channel	MS-J9	5.7	456	934	105%	134	153	14%
12	Main Channel at Judge Orr Road	MS-J11	6.7	482	997	107%	150	187	25%
13	Confluence of West Fork and Main Channel	MS-J12	11.2	615	1780	189%	240	346	44%
14	Main Channel at Falcon Highway	MS-J16	13.4	662	1907	188%	271	412	52%
15	Main Channel at Peyton Highway	MS-J19	15.1	683	1906	179%	285	428	50%
16	Main Channel at Jones Road	MS-J20	15.6	688	1913	178%	291	440	51%
17	South Fork at Jones Road	SF-J4	1.3	117	117	0%	41	41	0%
18	Confluence of South Fork and Main Channel	MS-J22	17.9	764	1989	161%	341	494	45%
19	Southeast Fork at McDaniels Road	SE-J3	2.4	157	153	-2%	69	69	0%
20	Main Channel at McDaniels Road	MS-J29	19.6	790	1985	151%	355	521	47%
21	Total Combined Outfall	SE-J3 plus MS-J29	22.0	909	2071	128%	424	590	39%

The 5-year storm event future undetained peak flow is estimated to increase by 128% over the existing peak flow while the future volume of runoff is estimated to increase by 39%.

Table 6.3: Summary of Flows at Selected Design Points – 10-year Storm Event

Design Point ID	Design Point Location	Hydrologic Element	Accumulative Area (mi ²)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	% Difference Peak Flow	Existing Volume (ac-ft)	Future Volume (ac-ft)	% Difference Volume
1	Haegler Diversion at Eastonville Road	HD-J2	0.8	210	571	171%	42	56	34%
2	West Fork at Eastonville Road	WF-J1	0.3	69	208	202%	16	23	47%
3	Main Channel at Eastonville Road	MS-J4	1.3	364	639	76%	59	75	27%
4	Haegler Diversion at Highway 24	HD-J4	1.3	245	642	162%	51	68	34%
5	West Fork at Highway 24	WF-J3	0.4	96	310	223%	26	35	37%
6	Main Channel at Highway 24	MS-J6	2.5	465	976	110%	101	122	21%
7	East Fork at Highway 24	EF-J4	1.2	518	564	9%	68	69	2%
8	Main Channel at Elbert Road	MS-J7	3.0	469	977	108%	113	133	18%
9	East Fork at Elbert Road	EF-J6	2.1	546	588	8%	98	100	3%
10	West Fork at Judge Orr Road	WF-J6	1.5	452	1089	141%	122	157	29%
11	Confluence of East Fork and Main Channel	MS-J9	5.7	829	1563	88%	221	244	11%
12	Main Channel at Judge Orr Road	MS-J11	6.7	890	1689	90%	248	295	19%
13	Confluence of West Fork and Main Channel	MS-J12	11.2	1170	3008	157%	404	536	33%
14	Main Channel at Falcon Highway	MS-J16	13.4	1280	3256	154%	463	641	39%
15	Main Channel at Peyton Highway	MS-J19	15.1	1334	3302	148%	493	673	36%
16	Main Channel at Jones Road	MS-J20	15.6	1348	3324	147%	505	693	37%
17	South Fork at Jones Road	SF-J4	1.3	212	212	0%	68	68	0%
18	Confluence of South Fork and Main Channel	MS-J22	17.9	1516	3484	130%	591	782	32%
19	Southeast Fork at McDaniels Road	SE-J3	2.4	269	264	-2%	111	111	0%
20	Main Channel at McDaniels Road	MS-J29	19.6	1581	3457	119%	623	832	34%
21	Total Combined Outfall	SE-J3 plus MS-J29	22.0	1820	3593	97%	734	943	29%

The 10-year storm event future undetained peak flow is estimated to increase by 97% over the existing peak flow while the future volume of runoff is estimated to increase by 29%.

Table 6.4: Summary of Flows at Selected Design Points – 100-year Storm Event

Design Point ID	Design Point Location	Hydrologic Element	Accumulative Area (mi ²)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	% Difference Peak Flow	Existing Volume (ac-ft)	Future Volume (ac-ft)	% Difference Volume
1	Haegler Diversion at Eastonville Road	HD-J2	0.8	431	1060	146%	77	96	25%
2	West Fork at Eastonville Road	WF-J1	0.3	146	389	166%	29	39	33%
3	Main Channel at Eastonville Road	MS-J4	1.3	730	1233	69%	112	135	20%
4	Haegler Diversion at Highway 24	HD-J4	1.3	521	1223	135%	97	121	24%
5	West Fork at Highway 24	WF-J3	0.4	224	605	170%	49	62	26%
6	Main Channel at Highway 24	MS-J6	2.5	997	1896	90%	194	225	16%
7	East Fork at Highway 24	EF-J4	1.2	1054	1113	6%	124	126	1%
8	Main Channel at Elbert Road	MS-J7	3.0	1010	1896	88%	220	253	15%
9	East Fork at Elbert Road	EF-J6	2.1	1120	1172	5%	183	187	2%
10	West Fork at Judge Orr Road	WF-J6	1.5	1017	2213	117%	244	291	19%
11	Confluence of East Fork and Main Channel	MS-J9	5.7	1817	3068	69%	429	467	9%
12	Main Channel at Judge Orr Road	MS-J11	6.7	1968	3383	72%	487	564	16%
13	Confluence of West Fork and Main Channel	MS-J12	11.2	2732	6104	123%	805	993	23%
14	Main Channel at Falcon Highway	MS-J16	13.4	3045	6784	123%	936	1191	27%
15	Main Channel at Peyton Highway	MS-J19	15.1	3200	6946	117%	1012	1269	25%
16	Main Channel at Jones Road	MS-J20	15.6	3250	7056	117%	1040	1308	26%
17	South Fork at Jones Road	SF-J4	1.3	454	454	0%	133	133	0%
18	Confluence of South Fork and Main Channel	MS-J22	17.9	3650	7392	103%	1210	1489	23%
19	Southeast Fork at McDaniels Road	SE-J3	2.4	547	546	0%	210	210	0%
20	Main Channel at McDaniels Road	MS-J29	19.6	3791	7525	99%	1293	1597	23%
21	Total Combined Outfall	SE-J3 plus MS-J29	22.0	4326	7687	78%	1503	1807	20%

The 100-year storm event future undetained peak flow is estimated to increase by 78% over the existing peak flow while the future volume of runoff is estimated to increase by 20%.

During the hydrologic analysis it was observed that the Black Squirrel Creek lies very close to the eastern boundary of the Gieck Ranch Basin from Falcon Highway downstream to Log Road. It is possible that flow from Black Squirrel Creek could spill into the Gieck Ranch Basin during extreme storm events. The flows in Black Squirrel Creek in this area are expected to be more than 5,000 cfs for the 100-year event. If the Black Squirrel Creek were to overflow its' banks and flow into the Gieck Ranch Basin it could increase the flows shown in the above tables. Possible improvements to address this potential problem include channel improvements to increase the Black Squirrel Creek conveyance in this area or constructing berms on the east bank to prevent overflow.

I. Reasonableness of Model Results

Several methods were used to assess the reasonableness of the computed peak flow rates. These include comparison to regional regression equations from the USGS report titled *Analysis of the Magnitude and Frequency of Floods in Colorado*, 2000, the Colorado Water Conservation Board (CWCB) Report titled *Guidelines for Determining 100-year Flood Flows for Approximate Floodplains in Colorado*, Version 6.0, 2004, and the U.S. Corps of Engineers’ *Hydrologic Analysis of Black Squirrel Creek*, draft report, 2003. Tables 7.1 through 7.4 provide comparisons of the model results from this study to these other methods. The comparisons were applied at design points representing confluences on the main stem, the two outfall sites at McDaniels Road and the combined outfall discharge. The tables are followed by a discussion of the methods and the comparison results. The Black Squirrel Creek Study (BSCS) did not include the Haegler Diversion or the additional drainage area in the southeast corner of the Gieck Ranch Basin that is included in this analysis. The data provided in the following tables for Black Squirrel Creek has been adjusted to account for this by multiplying the total drainage basin area by cfs/square mile values derived from the BCBS study.

Table 7.1: Reasonableness Check for 2-year Storm Event

Design Point ID	Design Point Location	Accumulative area (sq. mi.)	DBC DBPS HMS Results		USGS Regression Equations			Black Squirrel Creek Study			CWCB Regression Equation		
			Existing Q ₂ (cfs)	Future Q ₂ (cfs)	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future
11	Confluence of East Fork and Main Channel	5.7	204	462	91	-56%	-80%	101	-51%	-78%	N/A	N/A	N/A
13	Confluence of West Fork and Main Channel	11.2	260	866	126	-52%	-85%	199	-24%	-77%	N/A	N/A	N/A
18	Confluence of South Fork and Main Channel	17.9	309	927	159	-49%	-83%	319	3%	-66%	N/A	N/A	N/A
19	Southeast Fork at McDaniels Road	2.4	74	73	60	-18%	-18%	43	-41%	-41%	N/A	N/A	N/A
20	Main Channel at McDaniels Road	19.6	317	915	166	-48%	-82%	349	10%	-62%	N/A	N/A	N/A
21	Total Combined Outfall	22.0	367	968	175	-52%	-82%	392	7%	-59%	N/A	N/A	N/A

Table 7.2: Reasonableness Check for 5-year Storm Event

Design Point ID	Design Point Location	Accumulative area (sq. mi.)	DBC DBPS HMS Results		USGS Regression Equations			Black Squirrel Creek Study			CWCB Regression Equation		
			Existing Q ₂ (cfs)	Future Q ₂ (cfs)	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future
11	Confluence of East Fork and Main Channel	5.7	456	934	391	-14%	-58%	325	-29%	-65%	N/A	N/A	N/A
13	Confluence of West Fork and Main Channel	11.2	615	1780	513	-17%	-71%	642	4%	-64%	N/A	N/A	N/A
18	Confluence of South Fork and Main Channel	17.9	764	1989	619	-19%	-69%	1031	35%	-48%	N/A	N/A	N/A
19	Southeast Fork at McDaniels Road	2.4	157	153	279	78%	82%	140	-11%	-9%	N/A	N/A	N/A
20	Main Channel at McDaniels Road	19.6	790	1985	642	-19%	-68%	1129	43%	-43%	N/A	N/A	N/A
21	Total Combined Outfall	22.0	909	2071	673	-26%	-68%	1269	40%	-39%	N/A	N/A	N/A

Table 7.3: Reasonableness Check for 10-year Storm Event

Design Point ID	Design Point Location	Accumulative area (sq. mi.)	DBC DBPS HMS Results		USGS Regression Equations			Black Squirrel Creek Study			CWCB Regression Equation		
			Existing Q ₂ (cfs)	Future Q ₂ (cfs)	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future
11	Confluence of East Fork and Main Channel	5.7	829	1563	729	-12%	-53%	530	-36%	-66%	N/A	N/A	N/A
13	Confluence of West Fork and Main Channel	11.2	1170	3008	957	-18%	-68%	1045	-11%	-65%	N/A	N/A	N/A
18	Confluence of South Fork and Main Channel	17.9	1516	3484	1156	-24%	-67%	1678	11%	-52%	N/A	N/A	N/A
19	Southeast Fork at McDaniels Road	2.4	269	264	521	93%	97%	228	-15%	-13%	N/A	N/A	N/A
20	Main Channel at McDaniels Road	19.6	1581	3457	1199	-24%	-65%	1837	16%	-47%	N/A	N/A	N/A
21	Total Combined Outfall	22.0	1820	3593	1257	-31%	-65%	2066	13%	-43%	N/A	N/A	N/A

Table 7.4: Reasonableness Check for 100-year Storm Event

Design Point ID	Design Point Location	Accumulative area (sq. mi.)	DBC DBPS HMS Results		USGS Regression Equations			Black Squirrel Creek Study			CWCB Regression Equation		
			Existing Q ₂ (cfs)	Future Q ₂ (cfs)	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future	Q ₂ (cfs)	% Diff. Existing	% Diff. Future
11	Confluence of East Fork and Main Channel	5.7	1817	3068	3212	77%	5%	1376	-24%	-55%	3657	101%	19%
13	Confluence of West Fork and Main Channel	11.2	2732	6104	4181	53%	-32%	2715	-1%	-56%	5416	98%	-11%
18	Confluence of South Fork and Main Channel	17.9	3650	7392	5025	38%	-32%	4360	19%	-41%	7121	95%	-4%
19	Southeast Fork at McDaniels Road	2.4	547	546	2317	324%	325%	593	9%	9%	2248	311%	312%
20	Main Channel at McDaniels Road	19.6	3791	7525	5204	37%	-31%	4773	26%	-37%	7504	98%	0%
21	Total Combined Outfall	22.0	4326	7687	5446	26%	-29%	5366	24%	-30%	8029	86%	4%

The regional regression equations presented in U. S. Geological Survey Water Resources Investigations Report 99-4190, *Analysis of the Magnitude and Frequency of Floods in Colorado*, 2000 were based on stream gage data collected for unregulated streams in Colorado. Report 99-140 presents the following regional equations developed for the Plains Region of Colorado:

50.0% Chance (2-year return period) Peak Discharge

=

$39.0 \times (\text{Drainage Area})^{0.486}$

20.0% Chance (5-year return period) Peak Discharge

=

$195.8 \times (\text{Drainage Area})^{0.399}$

10.0% Chance (10-year return period) Peak Discharge

=

$364.6 \times (\text{Drainage Area})^{0.400}$

1.0% Chance (100-year return period) Peak Discharge

=

$1640 \times (\text{Drainage Area})^{0.388}$

Peak flows from the USGS regression equations varied from 56% lower to 324% higher than this planning study's computed existing flows and 71% lower to 325% higher than the computed future flows when taking into account all the design points and all return periods. For the 100-year return period, the regression equation resulted in a peak flow at the basin outfall that was 26% higher than the computed existing flows and 29% lower than the computed future flows. The high variability between the USGS method results and the model results can be attributed in part to the following factors:

1. The margin of error for the USGS Q_{100} equation is 300%, therefore it is not necessarily reliable.
2. The regression equations only include drainage area as a parameter, they do not account for rainfall, basin shape, slope, soil type, etc.
3. The equations are based on a limited number of gaging stations in the eastern plains, none of which were in the Black Squirrel Creek Basin.

The Black Squirrel Creek Study (BSCS) was conducted by the U.S. Army Corps of Engineers at the request of the Colorado Water Conservation Board (CWCB). The Black Squirrel Creek watershed is located in southeastern Colorado and measures 724 square miles at its confluence with the Arkansas River. The Gieck Ranch Drainage Basin is tributary to Black Squirrel Creek and was therefore included in the study.

Peak flows from the BSCS study varied from 51% lower to 43% higher than the computed existing flows and 78% lower to 9% higher than the computed future flows when taking into account all the design points and all return periods. For the 100-year return period, the study resulted in a peak flow at the basin outfall that was 24% higher than the computed existing flows and 30% lower than the computed future flows. Differences between the Black Squirrel Creek Study and the Gieck Ranch Basin model results can be attributed in part to the following factors:

1. The study was based on different soil data which appears to be less accurate.
2. The study was based on an equation for lag time, not detailed basin parameters. It also used a

more conservative (lower) Manning's n value resulting in a lower time of concentration.

3. The study was based on a SCS Type II storm while this analysis used a Type IIA storm.
4. The study used a higher percentage of imperviousness for existing low density development than was used in this analysis.

The regional regression equations presented in the Colorado Water Conservation Board Report titled *Guidelines for Determining 100-year Flood Flows for Approximate Floodplains in Colorado*, Version 6.0, 2004, *Analysis of the Magnitude and Frequency of Floods in Colorado*, 2000 were prepared using published 100-year hydrologic information in existing detailed floodplain reports. The CWCB prepared equations for hydrologic drainage area vs. discharge using a best-fit curve regression program. The 100-year peak flow equation for the Arkansas River Northern Foothills Sub-region (ARK-5) which includes the Gieck Ranch and Black Squirrel Creek Basins is:

$$Q_{100} = 1343.4 \times (\text{Drainage Area})^{0.578}$$

For the 100-year return period, the resulting peak flow at the basin outfall was 86% higher than the computed existing flows and 4% higher than the computed future flows. Differences between the CWCB method and the Gieck Ranch Basin model results can be attributed in part to the following factors:

1. The study was based on floodplain studies, not actual gage data.
2. The regression equations only include drainage area as a parameter, they do not account for rainfall, basin shape, slope, soil type, etc.

Generally, there is high variability in all the compared methods. The CWCB method yielded the highest peak flows. The USGS method and the Black Squirrel Creek Study resulted in 100-year peak flows that were within 26% of the existing conditions peak flow computed in this planning study and all three comparison methods were within +/- 30% of the future conditions peak flow which appears to be reasonable considering the factors listed above.

IV. Hydraulic Analysis

A. Introduction

This section summarizes the hydraulic analysis of the Gieck Ranch Drainage Basin. Included in this section are an inventory of existing drainageway structures and a summary of structure deficiencies, a description of the USACE HEC-RAS model, the 100-year existing conditions floodplain delineation with comparison to regulatory floodplains and a discussion of the 100-year future conditions floodplain. The floodplain information contained in this report is intended for the identification and mitigation of flood prone areas within the studied reach. It should only be used as a planning tool, and is not intended to replace the information presented in the El Paso County Flood Insurance Studies.

B. Hydraulic Structure Inventory and Evaluation

All of the existing drainage structures within the basin were identified and evaluated based on size, type, and general condition. The locations of the existing structures are identified in Figures 6.1, 6.2 and 6.3 which are located in Volume 2 of this report. The hydraulic capacity of existing culverts and bridges was estimated using either the CulvertMaster computer program by Haested Methods or the USACE HEC-RAS model. The hydraulic capacity of road crossings was based on the allowable cross flow defined in Table 6.1 of the Colorado Springs/El Paso County DCM for the functional classifications of the existing roadways identified in the El Paso County DOT 2030 Major Transportation Corridors Plan. A summary of the inventory and hydraulic capacity analysis is presented in Table 8.0 and the detailed analysis is provided in Section 12 of the Technical Addenda. During evaluation of the structures it was determined that El Paso County is not responsible for the maintenance and/or replacement for some structures, such as bridges and culverts under Highway 24. While these structures are included in the inventory tables, they were not evaluated for hydraulic capacity as indicated in Table 8.0.

In general, culverts inventoried for this study were found to have little capacity during the 100-year storm event before flood flows would overtop the road. Many were partially clogged with debris and/or sediment. A few were completely buried, possibly from roadside maintenance grading, and

were not found. In general, most of the existing bridge crossings were found to have adequate capacity during the 100-year storm event.

The diversion channel that conveys water from the Haegler Diversion drainageway to the West Fork drainageway north of Judge Orr Road was also evaluated for capacity. It was found to be inadequate to convey the existing 100-year flow.

C. Irrigation Structures

There are no irrigation canals located within the basin. The basin does have a number of stock watering ponds that have been constructed over time by local ranchers. These structures are meant to detain water during the spring runoff and during infrequent thunderstorms that occur over the basin. It is assumed that the structures will be removed as the basin develops or will be overwhelmed during a major storm event. Therefore, they were not evaluated as effective storage areas in the hydraulic analysis.

D. Hydraulic Model

Water surface elevations for the Gieck Ranch Drainage Basin were modeled using the U.S. Army Corps of Engineers direct-step-backwater computer model HEC-RAS version 4.0, dated May 2005. Water surface elevations were determined for the major stream reaches of the Gieck Ranch Drainage Basin identified in Figure 8.1 located in Volume 2 of this report. These stream reaches were first defined based on the ARC Hydro 1.1 GIS extension applied to the surface grid generated from the LIDAR terrain points within the ARCVIEW GIS 9.1 environment. Adjustments were made to stream reaches based on structure locations, El Paso County DOT review comments, and field investigations. The final stream delineations used in the HEC-RAS model closely match the reach delineations used in the HEC-HMS hydrologic model and follow the same naming convention with the one exception that some of the major drainageways have been further sub-divided within the HEC-RAS model as upper/middle/lower or North 1 (N1), North 2 (N2), South 1 (S1), South 2 (S2), etc., as shown on Figure 8.1.

Table 8.0: Structure Inventory and Evaluation Summary

Structure ID	Location	Type	Existing Condition	Percent of 100-year Flow Passing*	Adequate** Y/N?	Proposed Structure
1	Eastonville Road southeast of structure 2	18" CMP	Good	13%	N	2 - 6' x 3' CBC
2	Eastonville Road at Haegler Diversion	18" CMP	Good	3%	N	1 - 12' x 5' CBC
3	Eastonville Road northeast of structure 2	18" CMP	Good	67%	N	2 - 24" RCP
4	Eastonville Road at West Fork	36" CMP	Good	24%	N	48" x 76" ERCP
5	Eastonville Road northeast of structure 4	30" CMP	Fair	81%	N	2 - 30" CMP
6	Eastonville Road northeast of structure 5	18" CMP	Poor	100%	Y	---
7	Eastonville Road northeast of structure 6	18" CMP	Good	100%	Y	---
8	Eastonville Road northeast of structure 7	18" CMP	Good	93%	N	19" x 30" ERCP
9	Eastonville Road at Main Channel	24" CMP	Fair	2%	N	2 - 10' x 5' CBC
10	Eastonville Road at Main Channel - East Tributary	19" x 28" CMP	Good	4%	N	1 - 12' x 5' CBC
11	Eastonville Road northeast of structure 10	18" CMP	Good	100%	Y	---
12	Eastonville Road northeast of structure 11	24" x 35" CMP	Good	89%	Y	---
13	Eastonville Road at headwaters of East Fork	30" CMP	Good	24%	N	43" x 68" ERCP
14	Upstream of Hwy 24 at Haegler Diversion	2 - 36" CMP	Good	22%	N	2 - 8' x 4' CBC
15	Hwy 24 at Haegler Diversion	4' x 4' CBC	Good	34%	N.E.	---
16	Upstream of Hwy 24 northeast of structure 14	18" CI	Good	100%	N	24" CMP
17	Hwy 24 northeast of structure 15	24" RCP	Good	100%	N.E.	---
18	Upstream of Hwy 24 at West Fork	Bridge	Good	100%	Y	---
19	Hwy 24 at West Fork	Bridge	Good	100%	N.E.	---
20	Upstream of Hwy 24 northeast of structure 18	36" CMP	Good	72%	Y	---
21	Hwy 24 northeast of structure 19	24" CMP	Poor	34%	N.E.	---
22	Upstream of Hwy 24 at Main Channel	Bridge	Good	100%	Y	---
23	Hwy 24 at Main Channel	Bridge	Good	100%	N.E.	---
24	Upstream of Hwy 24 northeast of structure 22	24" CMP	Unknown	100%	Y	---
25	Hwy 24 northeast of structure 23	24" CMP	Unknown	100%	N.E.	---
26	Upstream of Hwy 24 northeast of structure 24	24" CMP	Unknown	100%	Y	---
27	Hwy 24 northeast of structure 25	24" CMP	Fair	100%	N.E.	---
28	Hwy 24 northeast of structure 27	24" CMP	Poor	99%	N.E.	---
29	Upstream of Hwy 24 at East Fork - West Tributary	24" CMP	Fair	6%	N	1 - 12' x 4' CBC
30	Hwy 24 at East Fork - West Tributary	24" CMP	Good	9%	N.E.	---
31	Upstream of Hwy 24 at East Fork - East Tributary	Bridge	Good	100%	Y	---
32	Hwy 24 at East Fork - East Tributary	Bridge	Good	100%	N.E.	---
33	Curtis Road south of Hwy 24	15" CMP	Good	6%	N	36" CMP
34	Elbert Road at East Fork	Bridge	Good	39%	N	50' Span

Table 8.0: Structure Inventory and Evaluation Summary (Cont.)						
35	Elbert Road south of structure 34	24" CMP	Good	100%	Y	---
36	Elbert Road at Main Channel	2 - 48" CMP	Good	19%	N	3 - 12' x 4' CBC
37	Elbert Road south of structure 36	24" CMP	Poor	55%	Y	---
38	Judge Orr Road at West Fork	67" x 95" CMP	Good	20%	N	4 - 12' x 5' CBC
39	Judge Orr Road east of structure 38	36" CMP	Good	100%	Y	---
40	Judge Orr Road west of structure 41	24" CMP	Poor	90%	Y	---
41	Judge Orr Road at Main Channel	Bridge	Good	100%	Y	---
42	Falcon Hwy at Main Channel	Bridge	Good	57%	N	85' Span
43	Peyton Road at headwaters of South Fork	24" CMP	Fair	75%	Y	---
44	Peyton Road at Main Channel	4 - 24" RCP	Good	2%	N	5 - 12' x 7' CBC
45	Peyton Road south of structure 44	36" CMP	Poor	100%	Y	---
46	Peyton Road south of structure 45	24" CMP	Good	100%	Y	---
47	East Garrett Road west of structure 48	24" CMP	Poor	100%	Y	---
48	East Garrett Road at South Fork	48" CMP	Good	14%	N	2 - 5' x 4' CBC
49	J.D. Johnson Road at South Fork	4 - 42" RCP	Good	63%	N	2 - 12' x 4' CBC
50	J.D. Johnson Road south of structure 49	30" CMP	Fair	56%	N	36" CMP
51	J.D. Johnson Road south of structure 50	30" CMP	Fair	100%	Y	---
52	Jones Road at Main Channel	60" CMP	Fair	4%	N	6 - 12' x 7' CBC
53	J.D. Johnson Road at Jones Road	30" CMP	Fair	55%	Y	---
54	Jones Road east of J.D. Johnson Road	30" CMP	Good	73%	Y	---
55	Jones Road at South Fork	36" CMP	Good	6%	N	2 - 7' x 5' CBC
56	Jones Road east of structure 55	30" CMP	Fair	67%	Y	---
57	J.D. Johnson Road at Main Channel US of structure 58	3 - 60" RCP	Good	14%	N	85' Span
58	J.D. Johnson Road at Main Channel	30" CMP	Good	1%	N	120' Span
59	J.D. Johnson Road and Log Road	24" CMP	Fair	23%	N	2 - 6' x 3' CBC
60	Main Channel at private driveway	48" CMP (est.)	Unknown	2%	N.E.	---
61	Log Road at Main Channel	Bridge	Good	36%	N	120' Span
62	McDaniel Road at Main Channel	30" x 48" Oval CMP	Good	1%	N	120' Span
63	Log Road and McDaniels Road	24" CMP	Good	2%	N	5 - 6' x 3' CBC

- * Road over-topping not included
- ** Allowable road over-topping included in adequacy analysis
- *** Based on proposed (with selected drainage basin plan) flows
- N.E. Not Evaluated, not EPCDOT responsibility

The HEC GEORAS 4.0 GIS extension was used to generate cross sections at 400 foot intervals along the stream flow paths. Cross-sections were then edited or added where needed to define roads, drainage structures, stock ponds, and changes in stream geometry. The stream cross-section data was then exported to the HEC-RAS model for further refinement and processing. This included defining channel overbank areas and assigning Manning's n values. For this study, the following Manning's n values were taken from Table 10.2 of the DCM (reference: Chow, Ven Te, 1959, Open Channel Hydraulics):

Minor stream on plain; winding, some pools and shoals, weeds and stones = 0.050

Same as above, sluggish reaches, weedy (overbank areas) = 0.070.

Additional model inputs included entering steady flow data from the HEC-HMS output, bridge and culvert details, junction information, reach lengths and ineffective flow areas. The existing conditions model was then run for the 2-year, 5-year, 10-year, and 100-year storm events using normal depth for boundary conditions. The model was run in the sub-critical mode. Using the sub-critical mode can result in lower velocities than other modes. Based on the results of the initial model run, some cross-sections were extended where needed and interpolated cross-sections were added as suggested by the HEC-RAS model. The revised model was then run to produce the final existing conditions results. Next, the existing conditions model was revised to incorporate future conditions hydrologic results to produce future conditions hydraulic model results.

E. Hydraulic Model Results

The results of the 100-year existing conditions model run were used to generate the proposed existing condition 100-year flood limits and to evaluate structures for adequacy as discussed previously. The existing condition model results are presented in the plan (PL) sheets in Appendix A and profile (PR) sheets in Appendix B and in Section 13 of the Technical Addenda.

While precise floodplain mapping is not a major goal of this study, comparison to established regulatory floodplains can give some insight to the model results. The existing condition HEC-RAS

flood limits differ from the approximate FEMA floodplain limits as shown in Figures 9.1, 9.2, and 9.3 which are located in Volume 2 of this report. Generally, the HEC-RAS flood limits are narrower than the FEMA floodplain. There are also a few areas where the two flood limits deviate, taking different flow paths. This can be attributed in-part to the fact that the FEMA floodplain is based on approximate methods using available data at the time of the initial FEMA FIS study (1997). The HEC-RAS analysis is a detailed study that is based on the most current data available and uses state of the art computer modeling programs.

The results of the 100-year future conditions model run were used to generate the future conditions un-detained 100-year flood limits for comparison purposes. The future conditions model results are presented in Section 14 of the Technical Addenda. Figures 10.1, 10.2, and 10.3 which are located in Volume 2 of this report show a comparison of the existing and the future un-detained 100-year flood limits. The future un-detained floodplain is approximately 83% larger than the existing conditions floodplain with an additional 1,115 acres of land inundated. There are approximately 11 buildings located within the existing conditions floodplain and 23 buildings located within the future conditions un-detained floodplain.

The depth of flooding within floodplain areas can be determined from the plan and profile sheets by subtracting the ground surface elevations from the water surface elevations at the appropriate cross-sections. For areas between cross-sections, the water surface elevation may be interpolated from two adjacent cross-sections. Because of certain limitations with the floodplain mapping, an individual survey is recommended for any structure or property that may be subject to a detailed evaluation for possible flood hazards. Such a survey should include more frequent cross-sections than used in this study and a field survey to obtain actual elevations and locations. This study is intended as a planning document only and, as such, has accuracy limitations that make it inappropriate for more detailed applications. These include final design of improvements located in or near the floodplain.

V. Environmental Evaluation

A. Introduction

Wetland delineation and environmental study work was completed within the Gieck Ranch drainage basin in El Paso County, Colorado for the following purposes:

- Identify and map jurisdictional wetlands and waters of the United States.
- Document and map existing vegetation and ecosystem types.
- Identify potential habitats for threatened and endangered species and document wildlife species that utilize the drainage basin.
- Document how current federal wetland regulations and mitigation guidelines apply to the proposed drainage basin project.

B. Methods - Field Delineation of Wetlands and Vegetation

Potential wetlands and waters of the United States within the Gieck Ranch Drainage Basin study area were field identified and delineated utilizing base United States Geological Survey topographical maps at a scale of 1:24,000. Within the Gieck Ranch drainage basin, the study area included Gieck Ranch Main Stem, Gieck Ranch East Fork Tributary, Gieck Ranch South Fork Tributary, Gieck Ranch West Fork Tributary, Haegler Diversion, and the Southeast Fork Tributary. Aerial photographs of the study area were examined prior to field work. Agencies contacted concerning the Gieck Ranch Drainage Basin project include the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service and Colorado Division of Wildlife.

Methods outlined in the “*Corps of Engineers Wetlands Delineation Manual*” (1987) were used to delineate wetlands and waters. Wetlands were identified using the three indicators of hydrophytic vegetation, hydric soils, and wetland hydrology. Vegetation was identified according to “*Weber*” (2001), and soil color data was obtained from the Munsell Color Chart (2000). Waters were defined according to channel and hydrological characteristics, such that a drainage channel with a defined bed and bank is considered jurisdictional waters by the Corps if the channel is connected to navigable water. Hydric soil indicators include dark soil colors with low chroma and value, redoxymorphic features (mottles), gleying, sulfidic odor, organic streaking, concretions, and high

organic content in the surface layer of sandy soils. Wetlands had soils that were saturated with water at or near the ground surface. Vegetation communities were identified in the field and using aerial photographs.

C. Wetland and Vegetation Community Descriptions

Potential wetlands and waters within the study area can be found in each of the six drainage sub-basins as shown on Figures 11.1, 11.2, and 11.3 located in Volume 2 of this report. In addition, environmental features have been mapped on the plan view sheets located included with this report. There may be isolated wetlands outside of the channel areas that may not be considered jurisdictional. The jurisdictional status of isolated wetlands and waters are determined on a case by case basis by the U.S. Army Corps of Engineers. An official determination as to whether impacted wetlands are isolated and/or jurisdictional should be made when any projects within the basin are proposed.

The Gieck Ranch Main Stem channel can be described as ephemeral, incised and eroded with a sand/gravel substrate. The remaining reaches are also ephemeral with an incised and eroded channel, although the creek frequently disappears and there is no observable flow in the channel. The lower portion of the basin contains ephemeral channels that are incised and eroded, having a sand and gravel channel bottom along the entire reach and no adjacent wetland vegetation.

Vegetation communities and ecosystem types at the Gieck Ranch Drainage Basin include shrublands and plains grasslands. Shrublands are vegetated with sandbar willow shrubs, and are usually intermixed with riparian forested areas and grasslands. The plains grassland areas within the drainage basin are vegetated mainly with grasses, nonnative weeds and wildflowers.

Dominant wetland vegetation along Gieck Ranch Basin includes sandbar willow (*Salix exigua*), peach leaved willow (*Salix amygdaloides*), wild plum (*Prunus americana*), Russian olive (*Elaeagnus angustifolia*), teasel (*Dipsacus fullonum*), curly dock (*Rumex crispus*), arctic rush (*Juncus arcticus*), Colorado rush (*Juncus confusus*), broad-leaf cattail (*Typha latifolia*), narrow-leaf cattail (*Typha angustifolia*), soft-stem bulrush (*Scirpus validus*), three-square (*Schoenoplectus*

pungens), prairie cordgrass (*Spartina pectinata*), redtop (*Agrostis alba*), foxtail barley (*Hordeum critesion*), wild licorice (*Galium circaezans*), plains cottonwood (*Populus deltoides*), narrowleaf cottonwood (*Populus angustifolia*) and sedges (*Carex* species). Four general wetland communities exist within the drainage basin: riparian forested wetlands, willow shrub wetlands, emergent wetlands, and open water wetlands.

Upland vegetation identified within the Gieck Ranch drainage basin includes ponderosa pine (*Pinus ponderosa*), western wheatgrass (*Pascopyrum smithii*), crested wheatgrass (*Agropyron cristatum*), smooth brome (*Bromus inermis*), mustard, alfalfa (*Medicago sativa*), kentucky bluegrass (*Poa pratensis*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), needle and thread grass (*Stipa comata*), cheatgrass (*Bromus tectorum*), blue gramma (*Bouteloua gracilis*), sideoats gramma (*Bouteloua curtipendula*), yucca, rabbit brush (*Chrysothamnus nauseosus*), cocklebur (*Xanthium strumarium*), snowberry (*Symphoricarpos oreophilus*), aster, daisy, thistle, and primrose. Much of the land within the drainage basin study area has been negatively impacted by nonnative weed species, overgrazing, suburban development activities, sedimentation and erosion.

D. Wetlands Classification, Functions and Values

Wetlands within the Gieck Ranch Drainage Basin can be classified for purposes of evaluation and management using the U.S. Fish and Wildlife Service's classification system (Cowardin et al., 1979). Delineated wetland and waters within the Gieck Ranch Basin can be classified within the palustrine system and the riverine system. The palustrine system contains most wetlands outside the creek conveyance channel, including wetlands dominated by shrubs, trees, grasses, and emergent plants. The riverine system includes the Gieck Ranch conveyance channel and the ephemeral drainages that occur throughout the project area that are classified as waters.

Functions and values of wetlands and waters within the Gieck Ranch Basin include wildlife habitat, food chain support, sediment trapping, nutrient retention, water purification, flood storage, shoreline anchoring, ground water recharge, ground water discharge and recreation. Soils in wetlands along the Gieck Ranch exhibit colors corresponding to 10yr2/1 and 10yr2/2 on the Munsell Soil Color Charts where organic soils have had time to develop and wetlands have not been disturbed or

covered by sediment. Soil colors correspond to 7.5yr3/3 and 10yr3/3 in wetlands where gravel is abundant, with redoxymorphic features being present in the soils. Wetlands quality ranges from low to moderate/high throughout the drainage basin.

E. Wildlife Species and Habitat

The Gieck Ranch Drainage Basin and associated wetlands provide wildlife habitat for the following species: deer, pronghorn, foxes, coyotes, raccoons, skunks, rabbits, weasels, squirrels, bats, badgers, rodents, prairie dogs, snakes, and amphibians. Common bird species which use the Gieck Ranch Basin include ducks, geese, coots, great blue herons, owls, nighthawks, snipe, killdeer, mourning doves, magpies, chickadees, crows, hawk, falcons, sparrows, woodpeckers, warblers, finches, robins, western tanagers, red-winged blackbirds, meadowlarks, juncos, grosbeaks, swallows, goldfinches, and flycatchers.

Existing willow shrub wetlands along the Gieck Ranch south of Falcon Highway may provide habitat for the threatened Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*), although this area is not shown on U.S. Fish and Wildlife Service maps as being known habitat for the mouse. A trapping survey for the Preble's Meadow Jumping Mouse may be required by the U.S. Fish and Wildlife Service prior to obtaining a Section 404 permit for the project.

F. Federal Section 404 Wetlands Regulations

Impacts to jurisdictional wetlands and waters of the United States are regulated through the Clean Water Act Section 404 permit process which is jointly administered by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. A Section 404 permit from the U.S. Army Corps of Engineers is required for impacts to wetlands and waters from filling, inundation and dewatering.

Discussions with representatives from the U.S. Army Corps of Engineers indicate that an individual Section 404 permit will most likely be required for proposed work in wetlands and waters for the Gieck Ranch drainage basin project. Given the requirements of the Section 404 permit program, 401(b)(1) guidelines, the design of the Gieck Ranch Drainage Basin improvements should avoid and

minimize impacts to wetlands and waters from the project to the maximum extent practicable. Individual permit applications are advertised for public comment and are reviewed by federal, state and local agencies. The processing of individual permits requires a minimum of 60-90 days, and wetland mitigation is required for impacts to jurisdictional wetlands and waters at a 1:1 mitigation replacement ratio.

Wetlands, streams and riparian areas along the Gieck Ranch Basin should be preserved and protected to the maximum extent practicable. Impacts to wetlands and waters should be avoided and minimized by the project design. All impacts to wetlands and waters will need to be mitigated following a mitigation plan approved by the U.S. Army Corps of Engineers.

G. Mitigation Guidelines and Recommendations

The U.S. Army Corps of Engineers would like to see project design plans for the Gieck Ranch Basin that minimize hard-lining the channel, with an emphasis on vegetative restoration measures. The existing floodway channel should be maintained to allow for overbank flooding that promotes the use of the floodway and adjacent floodplain during storm events. Water storage facilities should avoid impacts to wetlands and the Gieck Ranch riparian corridor. A wetlands and riparian buffer zone should be established and preserved along the Gieck Ranch drainageways to protect aquatic resources.

Mitigation opportunities include wetlands restoration and creation along the wetter sections of Gieck Ranch tributaries, and restoration of riparian habitats. Wetlands creation and restoration work generally involves site grading, planting wetland plant species, and seeding with native wetlands seed. Mitigation bank credits could potentially be purchased to offset wetlands impacts that result from the drainage basin project in order to meet wetlands mitigation requirements, if mitigation bank credits are available. Section 404 permit authorization must be obtained from the U.S. Army Corps of Engineers prior to initiating work in jurisdictional wetlands. It is recommended that the Corps be contacted in advance of all proposed work activities that could impact wetlands or waters to insure compliance with current Section 404 wetlands regulations. Best Management Practices (BMP's) for erosion and sediment control should be followed during all project activities.

VI. Evaluation of Alternatives

A. Introduction

This section describes the process for the development of alternative plans for drainageway improvements within the Gieck Ranch Drainage Basin. If not mitigated, future development would cause 100-year return period peak runoff rates within the basin to increase from 4,326 cfs to 7,687 cfs, an increase of 78%. Total runoff volume from the basin would increase by 20% for the 100-year event. This would increase flood flows and thereby increase the size and elevation of the 100-year floodplain, increasing the number of buildings that could be potentially flooded. Many of the existing drainage structures would have insufficient capacity to pass the increased flood flows and could potentially be damaged as well. In addition, smaller rainfall events would produce more runoff volume due to the increase in impervious surface areas. The estimated increase in runoff volume from 2-year event is 56%. As a result, channel erosion could be expected. Feasible alternatives were identified to address these long-term affects of urbanization on the basin.

The development of alternatives was accomplished in a two-step process. In the first step, several possible alternatives were evaluated for feasibility using parameters compared on qualitative and relative quantitative bases. Based on the results of the first step, feasible alternatives were selected by the Sponsors for further evaluation and screening in the second step.

B. Planning Goals and Evaluation Parameters

During the planning study process several planning goals were developed as a basis for alternative evaluation. These were refined into 5 general planning goals that are identified as the following:

- Identify existing facilities that are impacted by the 100-year storm event and improvements that will be required to control flooding as a result of new development.
- Provide stormwater management within developing areas of the basin that reduce the affects of runoff and sedimentation and maintain channel stability in order to minimize improvements required on reaches downstream of developments.

- Maintain the natural configuration of the existing channel when practical to avoid impacts to environmental resources. When possible, provide stormwater management facilities that preserve or enhance existing drainageway and floodplain areas.
- Identify facilities which will minimize future operations and maintenance costs resulting from new development.
- Provide stormwater management facilities that enhance water quality and control erosion and sedimentation.

Based on these goals, the following list of parameters was developed to evaluate alternatives.

- a. cost,
- b. maintenance,
- c. flood damage reduction,
- d. channel stability,
- e. impact upon known environmental resources,
- f. impact upon existing and future thoroughfares,
- g. right-of-way and property acquisition,
- h. trails and open space
- i. stormwater quality

C. Alternative Solutions

Possible alternatives for floodplain management to be evaluated initially are as follows:

- Do-Nothing Approach – No improvements are made. Damage to facilities is repaired on an as-needed basis.
- Prudent Line Approach – Provide setback areas where no development can occur to allow for natural channel erosion and meandering.
- On-site Detention – Small on-site detention facilities are constructed to reduce peak discharge rates.
- Small Regional Full Spectrum Detention – Small regional full spectrum detention facilities are constructed to reduce peak discharge rates.

- Regional Detention – Large regional detention facilities are constructed to reduce peak discharge rates.
- Channel Stabilization – Channel banks are improved at selected sites using structural and/or non-structural methods to prevent erosion.
- Channelization – Channel is realigned and/or improved using structural and/or non-structural methods to reduce or amend floodplain limits.

The following sections describe the alternatives and discuss potential benefits and disadvantages of the alternative solutions.

1. Do-Nothing Approach

Of the possible alternatives, this is the approach with the lowest initial infrastructure costs. The concept is applicable to areas with defined and stable channel banks and well designated floodplain limits. Areas with poor vegetative cover are not suitable to this approach since they **would be subject** to increased erosion from floodwaters.

As development occurs within the basin and flows increase, channels that were stable in the past will become unstable and will begin to degrade. In addition, the potential for damage from extreme events increases as flood flows would be much higher. Therefore, maintenance and restoration costs could be much higher for this alternative than others. This alternative is not acceptable in developed areas, however it might be suitable in those reaches of the basin where little development is expected, as long as upstream flows are attenuated using other alternative methods.

2. Prudent Line Approach

This approach is similar to the do-nothing approach except that specific setbacks are established to provide sufficient space for future changes to the floodplain caused by the geomorphic response to changed conditions, as well as natural channel aggradation and degradation. Like the do-nothing approach, this also has low initial infrastructure costs, however, some improvements of selected reaches is required in the form of grade control structures or bank stabilization. This approach does require that potentially large areas of land be set aside and/or purchased. The

setback areas could be utilized to provide opportunities for multi-use development including open space parks, trails and greenways. This alternative does not provide flood damage reduction to structures located within the floodplain. The use of the prudent line approach is limited in applicability to specific areas as outlined in the EPC Engineering Criteria Manual Addendum. The limiting criteria includes open channel segments located downstream from land having greater than a cumulative 20 percent impervious surface cover under future conditions or the main channel lacks adequate conveyance capacity for the future conditions 10-year flows. In addition, channels with in-line detention ponds and channels with transitions to/from improved channels and bridges may not be appropriate for prudent line treatment.

3. Detention Facilities

Detention facilities are the most common alternative used for mitigating impacts as a result of development. Detention facilities provide temporary storage of stormwater that is released slowly to reduce the peak discharge. Three types of detention were considered for this study. They are on-site (local), small regional, and regional detention. On-site facilities usually are designed to control runoff from a specific land development site such as a commercial or industrial site, or a small single phase subdivision. According to the EPC DCM, small on-site detention facilities are not encouraged by the County, primarily due to problems associated with neglected maintenance. Therefore, their use should be reserved only where there are no other options.

Facilities that are designed as part of a planning process and are developed in a staged, regional plan are referred to as regional facilities. Regional facilities have an advantage over local detention because they are owned and maintained by the local public entity, managing district, or other entity. This allows maintenance to be performed which often is overlooked or neglected with local detention facilities. Compared to on-site facilities, regional detention facilities require overall less land area and are more cost effective to construct and maintain. Regional facilities also offer opportunities for achieving multi-use goals such as open space parks and trails, recreation, and wildlife habitat. The common disadvantage of regional facilities is the potential lack of upfront funding for construction early in the development process and the availability of

land. Another disadvantage is that upstream reaches are subject to increased flows and reduced water quality that have to be mitigated.

Small regional facilities are designed to control runoff from more than one site but typically serve smaller areas than regional facilities. Small regional facilities have similar benefits and disadvantages as regional facilities, the main difference being that facility maintenance may be the responsibility of a landowner or home owners association or other managing district rather than a public entity.

A common impact of urbanization seen along ephemeral streams and upland prairie swales used to convey stormwater is rapid degradation and bank erosion. This can be caused by increased peak discharges and/or increased volume of runoff being discharged. Recent research has identified a need for improved detention sizing practices resulting in what is termed as “full spectrum detention” (Wulliman and Urbonas, 2005, provided in Section 20 of the Technical Addenda). The goal of the full spectrum approach is to obtain peak flows that are close to pre-development conditions over a full spectrum of runoff events, not just the extreme events. Research has shown that detaining the excess urban runoff volume (difference between pre-developed and developed condition volume of runoff) and releasing it over a 72 hour period results in peak flows that closely match pre-development flows for smaller, more frequent storms. This is accomplished through a modification to the orifice plate, overflow weir and pipe-inlet control, and basin geometry. Specific sizing criteria for full spectrum detention has been added to the recently updated UDFCD Drainage Criteria Manual (January, 2007). One limitation to full spectrum detention is that it is not recommended for contributing drainage areas greater than 1 square mile, therefore it is not feasible with large regional ponds. Full spectrum can be used with smaller regional ponds. Concerns regarding full spectrum detention include sediment accumulation and outlet structure maintenance.

4. Channel Stabilization

While detention facilities address the peak discharge portion of the urbanization effects along some reaches, it does not address the total volume of water discharged. Urbanization increases

the number of storms that create runoff, and increases the overall volume of runoff discharged from a site. In a newly developed area, this increased volume of runoff leads to elevated soil moisture in the drainageways. Native vegetation that is adapted to periodically moist soils begins to “drown” and die off in the wet channel conditions. Erosion of the channel begins as the roots that used to hold soils in place disappear. In-stream measures are needed to keep the receiving waterways from undergoing undesirable geomorphic changes. Measures to be considered for use in combination with any of the detention methods described above include vegetation augmentation and selective channel stabilization using structural methods and/or bio-engineered channels.

With vegetation augmentation, better adapted native hydric species are used to augment the existing vegetation early in the process when stormwater runoff is first introduced. This allows the dry channel to transform to a wet channel while not permitting the loss of soils.

Selective channel stabilization includes a number of structural methods to reduce erosion of channel banks where needed at selected sites. Stabilization usually involves armoring of the channel banks with riprap or a combination of riprap with other bioengineered stabilization measures. Bioengineered channels emphasize the use of vegetative components in combination with structural measures to stabilize and protect stream banks from erosion. Selective channel stabilization is particularly effective in areas where channel erosion is already occurring and protection of property and improvements is required. Grade control structures to prevent head-cutting of the channel invert may be required with this approach.

5. Channelization

Channelization involves the use of constructed, lined channels to control flood flows around or through urbanized areas. They are generally lined with riprap and are the most expensive of the alternatives considered. This alternative has a high potential for impacts to environmental resources also. Grade control structures would also be required with this approach, adding to the infrastructure costs.

D. Evaluation Matrix

An evaluation matrix was developed to assist in the initial development of the possible alternatives. The matrix is presented in Table 9.0 where alternatives are ranked relative to each other for each of the evaluation parameters.

Table 9.0: Alternatives Evaluation Matrix

Parameter	Alternative						
	Do - nothing	Prudent Line	On-Site Detention	Regional Detention	Small Regional Full Spectrum Detention	Channel Stabilization	Channel -ization
Infrastructure costs	Good	Good	Fair	Poor	Fair	Fair	Poor
Maintenance	Poor	Good	Fair	Fair	Fair	Good	Fair
Flood damage reduction	Poor	Fair	Good*	Good	Good*	Poor	Poor
Channel stability	Poor	Poor	Fair	Fair	Fair	Good	Good
Environmental impacts	Good	Fair	Fair	Fair	Fair	Fair	Poor
Impacts on roads	Poor	Poor	Good	Good	Good	Good	Good
R-O-W/property	Good	Poor	Good	Fair	Fair	Good	Good
Trails and open space	Fair	Good	Poor	Good	Good	Poor	Poor
Stormwater quality	Poor	Poor	Good	Fair	Good	Fair	Fair

*Good rating applies only if properly maintained. Studies have shown that this is not typical when the facilities are privately owned.

E. Feasible Alternatives - Conclusions and Recommendations

Based on the hydrologic and hydraulic analyses and the initial evaluation of alternatives, the following conclusions are made and strategies are recommended for further evaluation in Step 2 of the process:

1. Different areas of the basin will be subjected to differing levels of development. The majority of the high density development is expected to occur in the northwest and central sections, whereas the northeast and southern sections are expected to remain less developed. Different alternative approaches should be used for the different areas.
2. The do-nothing approach is not suitable for use in developed areas. It can be applied to specific reaches that are stable and do not expect to see any significant impacts from development, such as

the northeast and southern sections of the basin. It is expected that some selective channel improvements will be required on an as-needed basis for channels where the do-nothing approach is utilized.

3. The prudent line approach should not be used unless it meets the established criteria and can be combined with a specific multi-use function due to the high cost of property acquisition.
4. The use of on-site detention should be reserved to areas where there are no other options.
5. Regional detention facilities should be considered as an alternative to control cumulative increased flows from developed areas.
6. Small regional ponds with full spectrum detention should be considered as an alternative to control peak discharges from the highly developed areas. Full spectrum detention sizing methods, as outlined in the UDFCD Drainage Criteria Manual, should be required for these facilities. This will minimize the impacts to downstream reaches.
7. Selective channel stabilization should be used where needed. It is anticipated that in-stream stabilization measures will be needed downstream of developed sites to offset the impact of increased runoff volume. Vegetation augmentation and bio-engineered channels should be utilized as much as possible.
8. Channelization should be minimized due to the high cost and high potential for impacts to environmental resources.

Based on the above, two alternatives for detention were selected for further analysis, small regional ponds with full spectrum detention and regional detention ponds.

F. Stakeholder Involvement and Selection of Preferred Alternative

In order to evaluate the two alternatives for detention, the location and sizing of the ponds was determined, channel alternatives were applied, and comparative cost estimates were completed for each alternative. A stakeholder meeting was then held where input was solicited on the two alternatives. The following sections describe the alternatives analysis and results of the stakeholder meeting and selection process.

1. Location and Sizing of Ponds

For small regional detention, 15 full spectrum detention ponds were located inside the Meridian Ranch, Four-Way ranch, and Santa Fe Springs Developments, adjacent to existing drainageways. Two additional regional ponds were located in areas outside of the proposed developments to attenuate flows from general development identified in the 2030 land use but not yet associated with a specific development project. For the regional detention alternative three regional ponds were placed downstream of major developments where major tributaries converge. Two of the regional ponds are non-jurisdictional and one is a State of Colorado jurisdictional pond as it stores more than 100 ac-ft of water.

All of the ponds were initially sized using the Urban Drainage Detention Volume Estimating Handbook (UD-Detention v2.02.xls), revised in January 2007 to include full spectrum detention. The pond stage-discharge relationships were then used in revised HEC-HMS models to assess the effects of the detention pond alternatives and determine final pond sizes. The final pond volumes were increased by 25% to account for freeboard and final grading requirements. The land area required for each of the ponds was then calculated and increased by 20% to account for maintenance access requirements. Pond sizing calculations are provided in Section 15 of the Technical Addenda.

2. Channel Alternatives

The following assumptions on channel improvement alternatives were made for cost estimating and comparison purposes:

Small Regional Full Spectrum Alternative:

1. Channels upstream of the first small regional detention pond on a drainageway will require selective stabilization and/or channelization.

2. Channels immediately downstream of detention ponds will require vegetation augmentation only. Channels further downstream will require selective stabilization.
3. As-needed selective improvements will be required for reaches where the do-nothing approach is used.

Regional Detention Alternative:

1. Channels upstream of the first regional detention pond on a drainageway will require selective stabilization and/or channelization.
2. Channels downstream of detention ponds will require selective stabilization and/or channelization.
3. As-needed selective improvements will be required for reaches where the do-nothing approach is used.

For both alternatives it was assumed that selective stabilization would be applied to 25% of each designated reach length in areas to be developed and 10% in undeveloped areas where as-needed improvements are required. Channelization would be applied to 50% of each designated reach length. In addition, it was assumed that 150 grade control structures would be required. For small regional detention, it was assumed that vegetation augmentation would be applied to 50% of each designated reach length. Figures 12.1 and 12.2 located in Volume 2 of this report show the pond locations and proposed channel improvements for the small regional detention alternative. Figures 13.1, and 13.2, also located in Volume 2, show the pond locations and proposed channel improvements for the regional detention alternative.

3. Comparative Cost Estimates

Comparative costs estimates were prepared for improvements associated with the two detention alternatives. The cost estimate sheets with supporting assumptions and calculations are provided in Section 16 of the Technical Addenda and a summary of the estimates is presented in Table 10. These estimates include the detention pond and channel improvement costs only. Road crossing improvements for deficient structures are not included in this comparison. Land costs are not included for the small regional full spectrum ponds as it was assumed that they would not be owned and operated by El Paso County. From this it can be seen that the small regional detention

alternative is less expensive than regional detention due to the high cost of land acquisition and the extensive channelization that would be required for regional ponds.

Table 10: Comparative Costs for Detention Alternatives

Component	Small Regional	Regional
Detention Ponds - Construction Cost	\$8,119,290	\$5,700,500
Detention Ponds - Land Cost	\$1,350,000	\$6,075,000
Channel Improvements	\$10,162,152	\$18,645,676
Total	\$19,631,442	\$30,421,176

4. Preferred Alternative Selection

A public meeting was held on June 6, 2007 to present the results of the alternative analysis and receive feedback from stakeholders so that a preferred alternative could be selected. In addition to the developers, their consultants, and EPCDOT personnel, other invitees included regulatory agency representatives and members of the public. No regulatory agency representatives attended the meeting. Based on input from those that did attend, it was decided to proceed with small regional full spectrum detention as the preferred alternative. For the Santa Fe Springs Development, the owner(s) have expressed a desire to minimize the impact to the existing channels. They are proposing to include large setbacks and open space areas adjacent to drainageways and to utilize vegetation augmentation and bio-engineered stabilization as much as possible.

VII. Drainage Basin Plan Development

A. Selected Plan

The selected plan consists of integrating the selected alternative outlined in the previous section. This includes the construction of the small regional full spectrum detention basins and the recommended channel improvements shown on the plan and profile sheets located in the Appendices. The future conditions hydrologic and hydraulic models were updated to determine the affect of the full spectrum regional ponds on peak flows, volumes and channel velocities. Revised hydrologic and hydraulic modeling results are provided in Sections 17 and 18 of the Technical Addenda. Table 11 presents a summary of discharge rates for the selected plan incorporating the full spectrum regional detention facilities.

Table 11: Summary of Flows at Selected Design Points – Selected Plan Developed Conditions

Design Point ID	Design Point Location	Hydrologic Element	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q100 (cfs)
1	Haegler Diversion at Eastonville Road	POND HD-S1	5	25	32	338
2	West Fork at Eastonville Road	WF-J2	2	17	45	114
3	Main Channel at Eastonville Road	POND MS-S1	28	119	253	573
4	Main Channel Tributary 2 at Eastonville Road	POND MST2-S1	21	65	126	271
5	East Fork Tributary at Eastonville Road	EFT1-B1	25	46	73	134
6	East Fork at Eastonville Road	EF-B1	33	59	92	168
7	Haegler Diversion at Highway 24	HD-J4	7	33	138	429
8	West Fork at Highway 24	WF-J3	6	38	97	242
9	West Fork Tributary at Highway 24	POND WFT1-S1	1	8	24	66
10	Main Channel at Highway 24	MS-J6	49	190	391	877
11	Main Channel Tributary 3 at Highway 24	MST3-B1	1	3	7	19
12	East Fork Tributary at Highway 24	EFT1-J2	43	95	164	337
13	East Fork at Highway 24	EF-J4	160	334	564	1102
14	Main Channel at Elbert Road (Further South of)	MS-B10	1	2	6	16
15	Main Channel at Elbert Road (South of)	MS-J8	1	3	6	18
16	Main Channel at Elbert Road	MS-J7	50	193	399	896

17	East Fork at Elbert Road	EF-J6	162	344	588	1169
18	Confluence of East Fork and Main Channel	MS-J9	160	390	775	1774
19	West Fork at Judge Orr Road	POND WF-SR1	18	86	273	753
20	Main Channel at Judge Orr Road (West of)	POND WF-S3	1	2	4	11
21	Main Channel at Judge Orr Road	MS-J11	154	407	828	1920
22	Confluence of West Fork and Main Channel	MS-J12	160	500	1085	2679
23	Main Channel at Falcon Highway	MS-J16	141	494	1103	2842
24	Main Channel at Falcon Highway (East of)	MS-B20	2	7	15	38
25	South Fork at Falcon Highway	SF-B1	4	13	27	65
26	Main Channel at Peyton Highway	MS-J19	150	520	1163	3003
27	South Fork at Peyton Highway	SF-J1	18	40	70	148
28	South Fork at J.D. Johnson Road	SF-J4	51	117	212	455
29	Main Channel at Jones Road	MS-J20	154	528	1179	3054
30	South Fork at Jones Road	SF-J5	54	124	226	484
31	South Fork Tributary at Jones Road	SET1-B1	24	47	78	152
32	Main Channel at J.D. Johnson Road (North)	MS-J21	154	529	1184	3068
33	Confluence of South Fork and Main Channel	MS-J22	188	602	1341	3449
34	Main Channel at J.D. Johnson Road (South)	MS-J23	193	612	1367	3520
35	South Fork Tributary at J.D. Johnson Road	SET1-J1	38	77	131	272
36	Main Channel at Log Road (North)	MS-J25	195	616	1375	3546
37	Main Channel at Log Road (South)	MS-J26	196	618	1378	3557
38	Southeast Fork at Log Road	SE-J2	70	145	247	498
39	Main Channel at McDaniels Road	MS-J29	199	626	1395	3594
40	Southeast Fork at McDaniels Road	SE-J3	73	153	263	537
41	Total Combined Outfall	MS-J29 and SE-J3	272	779	1657	4131

Comparison to the existing conditions flows presented in Tables 6.1 through 6.4 shows that implementation of the selected plan will result in developed peak discharge rates that are slightly lower than existing discharge rates. This should reduce potential for flood damage within the basin.

B. Small Regional Detention Basins

The recommended plan includes the construction of 17 small regional detention storage basins, 15 of which would incorporate full spectrum detention. Ponds WF-SR1 and MS-SR1 exceed the contributing area size limitation for full spectrum detention. For these two ponds, the water quality

control volume should be provided. Pond WFT1-S1 will only provide detention for the property located in Basin WFT1-B1 and the pond should be constructed when this property is developed. The locations of the basins shown on the plan sheets are conceptual. The final location and sizes of the basins are to be determined during final design of proposed development projects. It is possible that the location and basin size may vary from the conceptual design as long as sufficient detention storage is provided to meet required discharge rates and the excess urban runoff volumes are provided as outlined in the Urban Drainage and Flood Control District Criteria for full spectrum detention. Table 12 lists the detention basin data for the selected plan. Some areas of the drainage basin may encounter seasonal high ground water tables. Final sizing of the detention basins should be done in such a way as to minimize the need for underdrains.

C. Channel Improvements

Recommended channel improvements consist of vegetation augmentation, selective channel stabilization such as selectively armoring existing channel banks with riprap at outside channel bends and at bridge and culvert outlets, bio-engineered stabilization treatment, and low flow linings, some channelization, and construction of grade control structures. The recommended channel improvements have been selected to minimize environmental impacts and retain natural channel characteristics as much as possible since the basin is mostly undeveloped and the majority of the existing drainageways have not been disturbed at this time. There are large areas of the basin that are to remain as vacant or agricultural land based on the El Paso County 2030 Land Use Codes. Specific channel improvements to the drainageways in these areas were not recommended. It is assumed that these channels will remain in private ownership which lowers the feasibility of channel improvements that require permanent right-of-way or easements for construction and maintenance. The recommended approach for these areas is to provide as-needed improvements.

Table 12: Detention Basin Data

Basin ID	Excess Urban Runoff Volume (ac-ft)	Detention Storage Volume (ac-ft)	Discharge Rate (cfs)
HD-S1	21.4	41.0	345
HD-S2	2.4	7.0	92
WF-S1	7.3	17.0	115
WF-S2	2.7	13.8	134
WF-S3	4.3	9.0	11
WF-S4	29.7	52.0	359
WFT1-S1	2.2	9.0	70
WF-SR1	WQCV*	30.0	802
MS-S1	12.2	42.0	583
MS-S2	0.6	5.2	58
MS-S3	4.8	19.0	147
MS-S4	11.8	30.0	29
MS-S5	2.9	6.1	26
MS-SR1	WQCV*	50.0	2,900
MST2-S1	3.9	21.5	275
MST4-S1	6.4	20.0	137
MST5-S1	11.6	30.0	90

* Use Water Quality Control Volume

Table 13 lists the recommended approach to channel improvements on a reach by reach basis. As land development projects proceed within the drainage basin the location and specific type of selective channel improvements will need to be identified during the project design phase based on site specific conditions. There may be some overlapping of approaches between reaches. For example, some selective stabilization may be needed in reaches designated for vegetation augmentation and vice-versa. The methods outlined in the City/County Drainage Criteria Manual and the El Paso County Engineering Manual should be applied during final design analysis. Some specific channel improvements have been identified for several areas such as the Haegler Diversion channel upsizing and realignment at Judge Orr Road. These improvements are called out on the selected plan drawings.

Table 13: Channel Improvements By Reach

Drainageway	Reach ID	Reach Length (ft)	Channel Approach
Haegler Diversion	HD-R1a	3875	Selective Stabilization
Haegler Diversion	HD-R1b	5737	Channelization
Haegler Diversion	HD-R2	2826	Vegetation Augmentation
Haegler Diversion	HD-R3	2207	Selective Stabilization
Haegler Diversion	HD-R4	5161	Vegetation Augmentation
Haegler Diversion	HD-R5	3784	Selective Stabilization
West Fork	WF-R1	1775	Channelization
West Fork	WF-R2	2281	Vegetation Augmentation
West Fork	WF-R3	3029	Selective Stabilization
West Fork	WF-R4a	1717	Vegetation Augmentation
West Fork	WF-R4b	2001	Vegetation Augmentation
West Fork	WF-R4c	1601	Selective Stabilization
West Fork	WF-R4d	1198	Selective Stabilization
West Fork	WF-R5	1200	Selective Stabilization
West Fork	WF-R6	863	Selective Stabilization
West Fork	WF-R7a	2341	Vegetation Augmentation
West Fork	WF-R7b	1594	Vegetation Augmentation
West Fork	WF-R8a	4002	Selective Stabilization
West Fork	WF-R8b	1600	Selective Stabilization
West Fork - Trib. WF1	WFT1-RI	5601	Vegetation Augmentation
Gieck Main	MS-R1	2400	Vegetation Augmentation
Gieck Main	MS-R2	2000	Selective Stabilization
Gieck Main	MS-R3	1200	Selective Stabilization
Gieck Main	MS-R4a	1278	Channelization
Gieck Main	MS-R4b	1341	Channelization
Gieck Main	MS-R5	6181	Vegetation Augmentation
Gieck Main	MS-R6	804	Selective Stabilization
Gieck Main	MS-R7a	1554	Vegetation Augmentation
Gieck Main	MS-R7b	3191	Vegetation Augmentation
Gieck Main	MS-R7c	1354	Vegetation Augmentation
Gieck Main	MS-R8a	314	Vegetation Augmentation
Gieck Main	MS-R8b	783	Selective Stabilization
Gieck Main	MS-R8c	568	Selective Stabilization
Gieck Main	MS-R11a	3376	Selective Stabilization
Gieck Main	MS-R11b	2405	Selective Stabilization
Gieck Main	MS-R12	620	Selective Stabilization
Gieck Main	MS-R13	3158	Vegetation Augmentation
Gieck Main	MS-R14	7422	Selective Stabilization
Gieck Main	MS-R15	3306	Selective Stabilization
Gieck Main	MS-R16	2294	As-needed Improvements
Gieck Main	MS-R17	542	As-needed Improvements
Gieck Main	MS-R18	5457	As-needed Improvements
Gieck Main	MS-R19	1604	As-needed Improvements
Gieck Main	MS-R20a	1197	As-needed Improvements

Table 13: Channel Improvements By Reach, cont.

Drainageway	Reach ID	Reach Length (ft)	Channel Approach
Gieck Main	MS-R20b	1227	As-needed Improvements
Gieck Main	MS-R21a	1990	As-needed Improvements
Gieck Main	MS-R21b	1584	As-needed Improvements
Gieck Main	MS-R21c	2242	As-needed Improvements
Gieck Main	MS-R22	3360	As-needed Improvements
Gieck Main	MS-R23	3268	As-needed Improvements
Gieck Main	MS-R24	1927	As-needed Improvements
Gieck Main	MS-R25a	1603	As-needed Improvements
Gieck Main	MS-R25b	1615	As-needed Improvements
Gieck Main	MS-R25c	384	As-needed Improvements
Gieck Main	MS-R26	803	As-needed Improvements
Gieck Main	MS-R27	1597	As-needed Improvements
Gieck Main	MS-R28	3599	As-needed Improvements
Gieck Main	MS-R29	797	As-needed Improvements
Gieck Main	MS-R30	2004	As-needed Improvements
Gieck Main - Sub Trib M1	MST1-R1	4799	Selective Stabilization
Gieck Main - Sub Trib M2	MST2-R1	3896	Selective Stabilization
Gieck Main - Sub Trib M2	MST2-R2	6504	Vegetation Augmentation
Gieck Main - Sub Trib M3	MST3-R1	5599	As-needed Improvements
Gieck Main - Sub Trib M4	MST4-R1	6000	Selective Stabilization
Gieck Main - Trib. M5	MST5-R1	7200	Selective Stabilization
East Fork	EF-R1	2659	As-needed Improvements
East Fork	EF-R2	2400	As-needed Improvements
East Fork	EF-R3	4800	As-needed Improvements
East Fork	EF-R4	1122	As-needed Improvements
East Fork	EF-R5	2161	As-needed Improvements
East Fork	EF-R6	1410	As-needed Improvements
East Fork	EF-R7	4876	As-needed Improvements
East Fork - Trib. EF1	EFT1-R1	3200	As-needed Improvements
East Fork - Trib. EF1	EFT1-R2a	2400	As-needed Improvements
East Fork - Trib. EF1	EFT1-R2b	4041	As-needed Improvements
East Fork - Trib. EF1	EFT1-R3	2394	As-needed Improvements
South Fork	SF-R1	2017	As-needed Improvements
South Fork	SF-R2	4120	As-needed Improvements
South Fork	SF-R3	3063	As-needed Improvements
South Fork	SF-R4	1167	As-needed Improvements
South Fork	SF-R5	2434	As-needed Improvements
South Fork	SF-R6	4799	As-needed Improvements
South Fork - Trib. SF1	SFT1-R1	2400	As-needed Improvements
Southeast Fork	SE-R1	5596	As-needed Improvements
Southeast Fork	SE-R2	2786	As-needed Improvements
Southeast Fork	SE-R3a	3209	As-needed Improvements
Southeast Fork	SE-R3b	2940	As-needed Improvements
Southeast Fork - Trib. SEF1	SET1-R1	3301	As-needed Improvements

The criterion used for sizing proposed channel sections and determining channel armoring has been average channel velocity. A maximum permissible velocity of 5 feet per second was used in areas to be developed. This corresponds to EPC DCM Table 10-4 values for earth lined channels with 0% to 5% slopes for prairie type grasses. In order to minimize the need for hard-lining of channels, check or drop structures have been recommended to reduce the channel slope and to prevent head-cutting of the channel. For this report, drop structures have been designed for a maximum drop of 5 feet and check structures have been designed for a maximum of 2.5 feet. The grade control structures should extend to the channel banks to prevent head cutting at the ends of the structure. Extensive use of grade control structures has eliminated the need for the hard-lining of channels with riprap in almost all locations, allowing for the use of soft-lined channels instead. Low flow linings can be utilized to protect the channel from increased frequency and volume of runoff from minor storm events where native channels will be altered. Recommended design methodologies for grade control structures and low flow linings are presented in Chapter 10 of the City/County DCM and in Volume 2 of the Urban Storm Drainage Criteria Manual. The 100-year velocities shown on the plan sheets have been adjusted to account for recommended channel improvements. Supporting calculations are provided by reach cross-sections in Section 19 of the Technical Addenda.

D. Roadway Bridge and Culvert Replacements

Many of the roadway culverts and a few of the bridges were found to be deficient for the 100-year storm event. Recommended replacements are shown on the plan view sheets in Appendix C. The replacement structures were sized in accordance with the City/County Drainage Criteria Manual. Because of erosive soils, riprap armor protection of the channel and abutments at bridges is recommended. The riprap protection should extend on either side of the bridge and should be accompanied with a cutoff wall at the downstream end to prevent undercutting of the armor protection.

E. Impacts on Environmental Resources

The overall approach of the selected plan is to minimize environmental impacts and retain natural channel characteristics as much as possible. Still, there will be some potential impacts due to channelization in areas where it cannot be avoided, construction of detention basins, construction of

grade control structures and improvements made to culverts and bridges. Many of these impacts will be temporary in nature. Environmental impacts may be mitigated by the utilization of vegetation augmentation and bio-engineered channel stabilization where wetland vegetation is introduced.

F. Right-of-Way Acquisition

The drainageways that pass through areas to be developed should be in dedicated drainage tracts, easements or rights-of-way to provide access to maintain or improve the channels as needed. This is an issue that should be addressed through the development review and approval process. It is assumed that all of the small regional detention basins will be owned and maintained by private entities; therefore county access will not be required. One area where additional right-of-way may be required is at the Haegler Diversion channel on the north side of Judge Orr Road. The El Paso County Major Transportation Corridors Plan calls for widening of Judge Orr Road. The selected plan calls for the channel to be realigned so that it is not using the road embankment as one of the channel side slopes. Additional room will be needed to separate the channel from the roadway when this work is done. There are several deficient roadway structures where the adjacent channel invert will need to be lowered to accommodate a larger structure. Temporary construction easements may be required to do this work. No cost has been included in the fee estimates for temporary easements.

G. Stormwater Quality

In January 2006 the County adopted the El Paso County Addendum to the City of Colorado Springs Drainage Criteria Manual Volume 2: Stormwater Quality Policies, Procedures and Best Management Practices (BMPs) which has been incorporated into the El Paso County Engineering Criteria Manual as Appendix 1. The goal of the Addendum is to provide engineering criteria for water quality protection measures. In addition to establishing permitting, inspection, and enforcement policies, the addendum provides guidance and requirements for the selection of structural BMP's for new development. It is the responsibility of the entity conducting any land disturbance activity to submit a Stormwater Management Plan for temporary erosion control prior to the start of construction and to properly control surface runoff, erosion, and sedimentation during construction activities. It is important that the erosion control plan be adhered to and maintained as specified in the Addendum.

Permanent erosion control measures are also required for all developments. For detention basins, water quality pools are required to provide for sedimentation of suspended pollutants. With the full spectrum detention approach, the water quality control volume is incorporated into the excess urban runoff volume that is detained and released slowly. Additional water quality measures for the detention basins should include an inlet forebay, a permanent water quality pool near the outlet control structure, and the introduction of water tolerant vegetation in the water quality pool. Erosion control in channels includes the use of vegetation augmentation, selective channel stabilization, and the use of drop/check structures.

H. Phasing and Prioritization of Improvements

The timing of the construction of the detention basins, channel improvements and new roadway structures is dependent upon the development of the adjacent property. Improvements to the Haegler Diversion channel along the north side of Judge Orr Road as well as structure improvements along Judge Orr Road can be coordinated with the proposed road widening project. Where existing drainage facilities are inadequate, replacement of these structures will have to be funded through capital improvement or bridge replacement funds. The improvements have been prioritized as shown in Table 15 in the next section of this report.

Based on El Paso County requirements, any future development south of Falcon Highway will require an update to this DBPS and shall be performed by the developer.

VIII. Fee Development

A. Cost Estimates

Cost estimates for the detention basins, major drainageway channel improvements, and culvert and bridge improvements are presented in Tables 14 through 16 on the following pages. Culverts and bridges that are deficient under existing conditions flows are considered a County CIP cost and are not included in the basin fee calculations if the proposed flow is less than existing. Costs associated with potential utility relocations are not included, however, due to the rural nature of this drainage basin they are expected to be minimal. All of the estimates include 10% for engineering and surveying and a contingency mark-up of 20%. All of the small regional full spectrum ponds are assumed to be owned and operated by private entities; therefore land acquisition costs are not included. Land acquisition costs are included for the two small regional ponds that are not associated with any specific development.

The following assumptions were made in estimating the channel improvement costs:

1. One-half of the channel sections in reaches designated for channelization will remain in their natural state. The remaining one-half will be 100-year grass lined channels.
2. Twenty five percent of the channel sections designated for selective channel stabilization will need selective improvements. The remaining 75% will be left in their natural state.
3. One-half of the of the channel sections designated for vegetation augmentation will need improvements. The remaining one-half will be left in their natural state.
4. Ten percent of the of the channel sections designated for as-needed improvements will need selective channel improvements. The remaining 90% will be left in their natural state.

For the Haegler Diversion realignment, it was estimated that 16 acres of additional land would be needed to shift the channel away from the Judge Orr Road embankment. The land acquisition cost for the required right-of-way or easement is estimated to be \$27,000 per acre (60% of the purchase cost of \$45,000 per acre) for a total land acquisition cost of \$432,000.

B. Unplatted Acreage

A total of 13,749 acres are estimated to be currently unplatted based on data provided by the El Paso County Development Services Department. The developed basin is projected to have an average imperviousness of 9.5% based on the projected 2030 land uses. This corresponds to 1,306 unplatted impervious acres to be used in the calculation of drainage and bridge fees.

C. Fee Calculations

Table 17 at the end of this section provides the drainage and bridge fee calculations for the Gieck Ranch Basin. The drainage fee is calculated as \$14,586 per impervious acre, the bridge fee is calculated as \$1,345 per impervious acre, and the land acquisition fee is estimated to be \$1,364 per acre.

Table 14: Cost Estimate For Detention Basins

Sub-Regional Basin ID	Detention Storage (ac-ft)	Basin Size (ac-ft)	Basin Area (acre)	Avg. Depth (feet)	Excavation Volume (cy)	Excavation Cost	Outlet Structure Cost	Emergency Spillway Cost	Estimated Construction Cost	Required Area (acre)	Land Cost	Total Cost
HD-S1	41.0	51.3	12.8	4	82,683	\$ 578,783	\$ 50,000	\$ 28,939	\$ 657,723	15.4		\$ 657,723
HD-S2	7.0	8.8	2.2	4	14,117	\$ 98,817	\$ 10,000	\$ 4,941	\$ 113,758	2.6		\$ 113,758
WF-S1	17.0	21.3	5.3	4	34,283	\$ 239,983	\$ 20,000	\$ 11,999	\$ 271,983	6.4		\$ 271,983
WF-S2	13.8	17.2	4.3	4	27,729	\$ 194,104	\$ 10,000	\$ 9,705	\$ 213,809	5.2		\$ 213,809
WF-S3	9.0	11.3	2.8	4	18,150	\$ 127,050	\$ 10,000	\$ 6,353	\$ 143,403	3.4		\$ 143,403
WF-S4	52.0	65.0	16.3	4	104,867	\$ 734,067	\$ 50,000	\$ 36,703	\$ 820,770	19.5		\$ 820,770
WFT1-S1	0.0	0.0	0.0	4	0	\$ -		\$ -	\$ -	0.0		\$ -
WF-SR1	30.0	37.5	9.4	4	60,500	\$ 423,500	\$ 30,000	\$ 21,175	\$ 474,675	11.3	\$ 506,250	\$ 980,925
MS-S1	42.0	52.5	13.1	4	84,700	\$ 592,900	\$ 50,000	\$ 29,645	\$ 672,545	15.8		\$ 672,545
MS-S2	4.0	5.0	1.3	4	8,067	\$ 56,467	\$ 10,000	\$ 2,823	\$ 69,290	1.5		\$ 69,290
MS-S3	19.0	23.8	5.9	4	38,317	\$ 268,217	\$ 20,000	\$ 13,411	\$ 301,628	7.1		\$ 301,628
MS-S4	30.0	37.5	9.4	4	60,500	\$ 423,500	\$ 30,000	\$ 21,175	\$ 474,675	11.3		\$ 474,675
MS-S5	6.1	7.6	1.9	4	12,302	\$ 86,112	\$ 10,000	\$ 4,306	\$ 100,417	2.3		\$ 100,417
MS-SR1	50.0	62.5	15.6	4	100,833	\$ 705,833	\$ 50,000	\$ 35,292	\$ 791,125	18.8	\$ 843,750	\$ 1,634,875
MST2-S1	21.5	26.9	6.7	4	43,358	\$ 303,508	\$ 30,000	\$ 15,175	\$ 348,684	8.1		\$ 348,684
MST4-S1	20.0	25.0	6.3	4	40,333	\$ 282,333	\$ 20,000	\$ 14,117	\$ 316,450	7.5		\$ 316,450
MST5-S1	30.0	37.5	9.4	4	60,500	\$ 423,500	\$ 30,000	\$ 21,175	\$ 474,675	11.3		\$ 474,675
Subtotal:									\$ 6,245,608	147.1	\$ 1,350,000	\$ 7,595,608

Assumptions:

- 1) The basin size is approximately 1.25 times the detention storage size.
- 2) The required area for detention facilities is approximately 1.20 times the basin area.
- 3) Excavation costs of \$7.00 per cubic yard includes excavation, grading, seeding and appurtenanaces.
- 4) Land cost is not included if the pond is not owned and maintained by El Paso County.
- 5) Contingency and Engineering cost is applied to construction cost only, not land acquisition.

Contingency (20%): \$ 1,249,122
Engineering (10%): \$ 624,561

Total: \$ 9,469,290

Table 15: Cost Estimate Summary For Channel Improvements

No.	Proposed Improvement	Quantity	Unit	Unit Cost	Extended Cost
1	Grade Control Structures	148	EA	\$ 10,000	\$ 1,480,000
2	Grassed Lined Channelization	5,066	LF	\$ 160	\$ 810,560
3	Selective Channel Stabilization	16,743	LF	\$ 190	\$ 3,181,170
4	As-needed Selective Improvements	9,735	LF	\$ 135	\$ 1,314,225
5	Vegetation Augmentation	22,913	LF	\$ 45	\$ 1,031,085
Subtotal:				\$ 7,817,040	

Assumptions:

- (1) Items 2,3,and 4 include \$25 per L.F for wetlands mitigation.
- 2) Channalization is calculated for 50% of designated reach lengths.
- 3) Selective Channel Stabilization is calculated for 25% of designated reach lengths.
- 4) As-needed Selective Improvements are calculated for 10% of designated reach lengths.
- 5) Vegetation Augmentation is calculated for 50% of designated reach lengths.

Contingency (20%): \$ 1,563,408

Engineering (10%): \$ 781,704

Total: \$ 10,162,152

Table 16: Cost Estimate For Structures and Bridges

Structure ID	Location	Proposed Facility	Quantity	Unit	Unit Cost	Extended Cost	End Sections & Riprap	Channel Modifications				Total Cost	Structure Cost	Bridge Cost	County CIP Cost	Priority*
								Quantity	Unit	Unit Cost	Total Cost					
1	Eastonville Road southeast of structure 2	34" x 53" ERCP	50	LF	\$ 120	\$ 6,000	\$ 3,000					\$ 9,000	\$ 9,000			High
2	Eastonville Road at Haegler Diversion	12' x 5' RCBC	50	LF	\$ 550	\$ 27,500	\$ 8,250					\$ 35,750	\$ 35,750			High
3	Eastonville Road northeast of structure 2	24" RCP	50	LF	\$ 56	\$ 2,800	\$ 1,400					\$ 4,200	\$ 4,200			Low
4	Eastonville Road at West Fork	48" x 76" ERCP	50	LF	\$ 240	\$ 12,000	\$ 4,800					\$ 16,800	\$ 16,800			Medium
9	Eastonville Road at Main Channel	2-10' x 5' CBC	100	LF	\$ 500	\$ 50,000	\$ 15,000					\$ 65,000	\$ 65,000			High
10	Eastonville Road at Main Channel - East Trib	12' x 5' RCBC	50	LF	\$ 550	\$ 27,500	\$ 8,250					\$ 35,750	\$ 35,750			High
13	Eastonville Road at headwaters of East Fork	43" x 68" ERCP	50	LF	\$ 216	\$ 10,800	\$ 4,320					\$ 15,120	\$ 15,120			High
14	Upstream of Hwy 24 at Haegler Diversion	2 - 8' x 4' RCBC	100	LF	\$ 400	\$ 40,000	\$ 12,000	881	LF	\$ 100	\$ 88,100	\$ 140,100			\$ 140,100	Medium
20	Upstream of Hwy 24 northeast of structure 18	42" RCP	50	LF	\$ 100	\$ 5,000	\$ 2,500					\$ 7,500	\$ 7,500			Low
29	Upstream of Hwy 24 at East Fork - West Trib	12' x 4' RCBC	50	LF	\$ 450	\$ 22,500	\$ 6,750	711	LF	\$ 100	\$ 71,100	\$ 100,350			\$ 100,350	High
33	Curtis Road south of Hwy 24	2-43" x 68" ERCP	100	LF	\$ 216	\$ 21,600	\$ 8,640	401	LF	\$ 100	\$ 40,100	\$ 70,340	\$ 70,340			Low
34	Elbert Road at East Fork	50' Span	2,000	SF	\$ 135	\$ 270,000	\$ 10,000	857	LF	\$ 100	\$ 85,700	\$ 365,700			\$ 365,700	Medium
36	Elbert Road at Main Channel	3 - 12' x 4' RCBC	150	LF	\$ 500	\$ 75,000	\$ 22,500	419	LF	\$ 100	\$ 41,900	\$ 139,400			\$ 139,400	High
38	Judge Orr Road at West Fork	4 - 12' x 6' RCBC	288	LF	\$ 600	\$ 172,800	\$ 51,840	519	LF	\$ 100	\$ 51,900	\$ 276,540			\$ 276,540	High
39	Judge Orr Road east of structure 38	36" RCP	50	LF	\$ 80	\$ 4,000	\$ 2,000					\$ 6,000			\$ 6,000	Low
42	Falcon Hwy at Main Channel	85' Span	3,400	SF	\$ 135	\$ 459,000	\$ 10,000	258	LF	\$ 100	\$ 25,800	\$ 494,800			\$ 494,800	Low
44	Peyton Road at Main Channel	5 - 12' x 7' RCBC	250	LF	\$ 700	\$ 175,000	\$ 52,500	1,185	LF	\$ 100	\$ 118,500	\$ 346,000			\$ 346,000	High
48	East Garrett Road at South Fork	2 - 5' x 4' RCBC	100	LF	\$ 300	\$ 30,000	\$ 9,000	785	LF	\$ 100	\$ 78,500	\$ 117,500			\$ 117,500	High
49	J.D. Johnson Road at South Fork	2 - 12' x 4' RCBC	100	LF	\$ 450	\$ 45,000	\$ 13,500					\$ 58,500			\$ 58,500	Low
52	Jones Road at Main Channel	6 - 12' x 7' RCBC	300	LF	\$ 700	\$ 210,000	\$ 63,000	620	LF	\$ 100	\$ 62,000	\$ 335,000			\$ 335,000	High
55	Jones Road at South Fork	2 - 7' x 5' RCBC	100	LF	\$ 400	\$ 40,000	\$ 12,000	1,605	LF	\$ 100	\$ 160,500	\$ 212,500			\$ 212,500	High
57	J.D. Johnson Road at Main Channel US	85' Span	3,400	SF	\$ 135	\$ 459,000	\$ 10,000	1,011	LF	\$ 100	\$ 101,100	\$ 570,100			\$ 570,100	High
58	J.D. Johnson Road at Main Channel DS	120' Span	4,800	SF	\$ 135	\$ 648,000	\$ 10,000	1,596	LF	\$ 100	\$ 159,600	\$ 817,600			\$ 817,600	High
59	J.D. Johnson Road and Log Road	34" x 53" ERCP	50	LF	\$ 120	\$ 6,000	\$ 3,000					\$ 9,000			\$ 9,000	High
61	Log Road at Main Channel	120' Span	4,800	SF	\$ 135	\$ 648,000	\$ 10,000	611	LF	\$ 100	\$ 61,100	\$ 719,100			\$ 719,100	Low
62	McDaniel Road at Main Channel	130' Span	5,200	SF	\$ 135	\$ 702,000	\$ 10,000	453	LF	\$ 100	\$ 45,300	\$ 757,300			\$ 757,300	High
63	Log Road and McDaniels Road	5 - 6' x 3' RCBC	250	LF	\$ 300	\$ 75,000	\$ 22,500					\$ 97,500			\$ 97,500	High
New	Log Road Between S-60 and S-61	120' Span	4,800	SF	\$ 135	\$ 648,000	\$ 10,000	2,572	LF	\$ 100	\$ 257,200	\$ 915,200			\$ 915,200	High
New	Log Road at Southeast Tributary	2 - 10' x 3' RCBC	50	LF	\$ 400	\$ 20,000	\$ 10,000	1,200	LF	\$ 101	\$ 121,200	\$ 151,200			\$ 151,200	High
New	Rex Road at Haegler Diversion	30" RCP	100	LF	\$ 68	\$ 6,800	\$ 2,040					\$ 8,840	\$ 8,840			As Developed
New	Stapleton Road at Haegler Diversion	2-6'x4' Box Culverts	200	LF	\$ 300	\$ 60,000	\$ 18,000					\$ 78,000	\$ 78,000			As Developed
New	Judge Orr at Main Channel - Road Widening	Bridge Widening	2,400	SF	\$ 135	\$ 324,000	\$ 10,000					\$ 334,000		\$ 334,000		As Developed
New	Arroyo Hondo Northern Crossing	3-28'x6' Con Span Culverts	180	LF	\$ 1,500	\$ 270,000	\$ 10,000					\$ 280,000		\$ 280,000		As Developed
New	Arroyo Hondo Southern Crossing	6-28'x6' Con Span Culverts	360	LF	\$ 1,500	\$ 540,000	\$ 10,000					\$ 550,000		\$ 550,000		As Developed
New	La Bajada Parkway at West Fork	4-12'x6' Box Culverts	240	LF	\$ 600	\$ 144,000	\$ 43,200					\$ 187,200		\$ 187,200		As Developed
Subtotal:												\$ 346,300	\$ 1,351,200	\$ 6,629,390		

* Priority Ranking:

High Priority - Damage to existing structures is likely from high frequency flooding events.

Medium Priority - Damage to existing structures is likely from low frequency flooding events.

Low Priority - Damage to existing structures is not likely from most flooding events.

As-Developed - Improvements to be completed with associated adjacent developemnt

Contingency (20%): \$ 69,260 \$ 270,240 \$ 1,325,878

Engineering (10%): \$ 34,630 \$ 135,120 \$ 662,939

Total: \$ 450,190 \$ 1,756,560 \$ 8,618,207

Table 17: Proposed Drainage and Bridge Fees

Total Unplatted Acreage	13,749 acres		
Projected Unplatted Impervious Acreage	1,306 acres		
<u>Drainage Fee Calculation:</u>			
Total cost of reimbursable structures not classified as bridges		\$	450,190
Total cost of channel improvements		\$	10,162,152
Cost of detention facilities (not including land)		\$	8,119,290
Cost for Study Preparation		\$	318,000
Total cost contributing to the drainage fee		\$	19,049,632
	Drainage Fee	\$	14,586 per impervious acre
<u>Bridge Fee Calculation:</u>			
Total cost of reimbursable structures classified as bridges		\$	1,756,560
	Bridge Fee	\$	1,345 per impervious acre
<u>Land Acquisition Fee Calculation</u>			
Detention Pond Land Acquisition		\$	1,350,000
Haegler Diversion Realignment		\$	432,000
Total cost of land acquisition		\$	1,782,000
		\$	1,364 per impervious acre
	Total Fees	\$	17,296 per impervious acre