HORSE CREEK BASIN STUDY

March, 1989

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES

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State Engineer

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Crowley, El Paso, Elbert and Lincoln Counties
Colorado

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COLORADO DIVISION OF WATER RESOURCES

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CHAPTER 1

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of this study of the Horse Creek basin was to obtain adequate information through a comprehensive effort in order to develop an administration plan for water rights in the basin by March 1, 1989 pursuant to the order of the Water Court.

The Horse Creek basin is a complex and unique basin. The basin contains both intermittent streams that only flow in response to intense rainfall events and reaches that have a perennial baseflow of several cubic-feet per second. The perennial flowing streams are located below areas where springs discharge at the erosional contact of water-bearing materials of the Nussbaum formation with the underlying impermeable Pierre shale. Below these springs, areas of vegetation including native hay and other grasses consume most of this baseflow so that it does not reach the lower end of the basin until the evapotranspiration process declines or stops in the late fall.

In addition to the surface water flows, the basin has two distinct aquifers that have been developed to provide ground water for irrigation of crops. The administrative plan considers the interrelationship between the waters of these two aquifers and the streamflows which supply water for direct diversion and storage in reservoirs.

The area described in this report consists of approximately 1,070 square miles in eastern El Paso, southern Elbert, southwestern Lincoln, and Crowley counties, Colorado. It includes Horse Creek and all of its tributaries upstream of the Lake Henry-Sugar City area (Figure 1). The maximum north-south extent of the area is approximately 65 miles, and its width ranges from about 12 to about 20 miles.

CHAPTER 2

HISTORY OF WATER RIGHTS ADMINISTRATION

The waters of Horse Creek were first appropriated over one hundred (100) years ago. The oldest appropriation date on Horse Creek was determined to be December 8, 1888, in the general adjudication of April 4, 1905. This right actually lies downstream of the "Horse Creek Basin" for the purposes of this administrative plan. Subsequently, general adjudications confirming water rights on Horse Creek and its tributaries were finalized on August 30, 1922, February 3, 1927, and August 15, 1960. Other water rights have been adjudicated since the enactment of the Water Rights Administration and Determination Act of 1969.

Not surprisingly, the most senior water rights on Horse Creek are located very near the mainstem of the Arkansas River. As late as the general adjudication of 1960, appropriations that were initiated in 1919 were still being decreed.

In the 1930's a record of diversions was maintained for certain structures in the basin, and by the 1960's additional records were obtained within the basin, however, no early administrative activity was necessary in Horse Creek Basin. The impetus for administration was the drought of the 1950's according to Kenneth Carter (January, 1989 interview), of the Box Springs Canal and Reservoir Company (Box Springs).

The earliest controversy of record was resolved through a stipulated settlement in civil action 3069-3096. The parties to the case were Box Springs and the Hixson Ranch Company. A stipulation on April 29, 1966 was entered by the parties finding that certain wells and sumps owned by Hixson did affect Horse Creek and others did not. No administrative action was described in the stipulation and the court apparently did not adopt or confirm the stipulation. The case was dismissed on April 20, 1970.

The first recorded requests for administration were in response to upstream diversions of groundwater and surface water. Downstream senior surface water diverters claimed the upstream diversions affected the senior surface rights. Box Springs first requested State Engineer Ralph Owens to discontinue the issuance of well permits in the basin in January of 1969. Later, in January of 1973, Box Springs complained to Division Engineer Rudy Styduhar about "impediments and diversionary structures" and "wells and open pits" affecting Horse Creek. In December, 1973, Box Springs complained to State Engineer Clarence Kuiper and placed a call on the entire upper basin.

These "calls" required conjunctive groundwater/surface water administration. The integration of groundwater and surface water was evolving in Colorado at that point in time. Fellhauer v. People, 167 Colo. 320, 447 P.2d 986 (1968) had only recently been decided and the Rules and Regulations Governing the Use, Control, and Protection of Surface and Ground Water Rights in the Arkansas River and its Tributaries had recently been promulgated.

A review of the State Engineer's office records shows that applications for new large capacity wells have been denied since 1969 throughout the Horse Creek Basin because the basin was overappropriated. New irrigation wells were constructed between 1969 and 1973 with valid permits issued prior to April 21, 1967.

It was in this setting that Rodney J. Preisser filed applications for ground water rights in cases W-2545 and W-3890 in 1972. The 14 large capacity wells which were permitted in April 1965 were located in the upper reaches of the basin near the headwaters. The court decree was entered by Judge Gobin on September 25, 1973 and his decision was upheld on appeal by the Colorado Supreme Court on February 20, 1976. The decrees contain language which explicitly recognized that the Preisser rights can be called out to protect senior basin rights.

On July 7, 1976, Smith Cattle Co., Inc. (Smith Cattle) requested curtailment of the Preisser wells. Division Engineer Robert Jesse was faced with the problem of deciding how best to administer the ground water rights of Preisser and the senior surface water rights of Smith. Rather than total curtailment, the partial curtailment approach of the Arkansas Rules and Regulations was ordered. In so doing, Mr. Jesse explicitly established that this administrative action was in response to a local (in-basin) call rather than an Arkansas River call.

On May 20, 1977, however, Mr. Jesse ordered strict priority administration of the Preisser wells. This administrative principle was extended to the wells owned by W. Ralph Book on May 25, 1977.

Concurrent with these efforts to establish conjunctive administration within the basin, various agreements were made. Mr. Elvin Kuester agreed to regulate his diversions out of Steels Fork into Little Horse Creek from October, 1976 to October, 1977. Mr. Jesse also investigated why summer thundershower floods on Upper Horse Creek did not reach the Box Springs diversion during June, 1977.

During the following 3 1/2 years, priority administration remained the accepted rule for all water rights in the basin. In response to written calls made by Box Springs and Smith Cattle, dated March 12, 1981 and July 3, 1981, respectively, Division Engineer Jesse reconfirmed his May, 1977 orders to Preisser and Book. Additionally, on July 14, 1981, Jesse ordered curtailment of water rights junior to Box Springs owned by Smith Cattle and Reid Cattle Companies. This action caused Smith and Reid to object, claiming that the Box Spring call was futile. In support of this claim, Smith and Reid's attorney asserted that the matter had been "settled in prior litigation" (civil action 3069-3096.)

After consultation with many of the affected parties, Mr. Jesse rejected priority administration by rescinding his orders of July 14, 1981 and readopting Arkansas Rules as the appropriate means of applying conjunctive administration within the Horse Creek basin on January 7, 1982. Mr. Jesse also determined that Box Springs calls on junior surface decrees (described as

"Steel Fork Creek decrees") are futile. Accordingly, administrative orders were reissued to Gardner (Preisser) and Book, and extended to Donald V. Johns and Gerald V. Hoover in July, 1982. Furthermore, although apparently no specific order was issued to the successors of Hixon (now Horse Creek Grazing Association), there is evidence that shows the association agreed in July, 1982 to be subject to the Arkansas Rules. No extension of the application of administrative orders pursuant to the Arkansas Rules, other than periodic renewals to Preisser and their successors, occurred until 1985. On July 19, 1985, Assistant Division Engineer Kenneth Cooper issued letters that were sent to Preisser, Smith Cattle, and Reid Cattle reaffirming the general applicability of Arkansas Rules--even to the extent that the use of an individual's wells might be curtailed to prevent injury to the same party's senior surface rights.

SRJ I Venture (SRJ) acquired six (6) of the fifteen (15) wells decreed in case nos. W-2545 and W-3890, that were formerly owned by Preisser prior to September, 1986. In October 1986, the current case, 86CW91 was filed. Traveler's Insurance Company (Travelers) is also a party to the case.

To bring this summary current, on October 20, 1988, Travelers requested the Division Engineer to investigate and order the removal of twenty-six (26) undecreed small storage reservoirs on the Smith Cattle Ranch on Steeles Fork. Travelers maintained that if there is shortage of water for Smith Cattle and Reid Cattle, it must be due in part to these structures. After investigation and confirmation of the validity of Smith and Reid calls, an order was issued on December 30, 1988 to Smith Cattle to breach or in the alternative to modify the outlet works of such structures so as to bypass all inflow by no later than April 1, 1989.

This historical review documents that in order to protect the availability of water to senior rights while maximizing the beneficial use of the resource, a comprehensive basin management approach is required.

CHAPTER 3

APPROACH

The court's order of August 30, 1988 required the State Engineer to develop a plan of administration for the specific water rights that were being litigated in court case 86CW91 as well as other rights in the basin. The court did not define the "basin". The State Engineer assigned staff from both the Division II and Denver offices to develop the required operating plan and several meetings were held in September 1988 to define specific work tasks. Since then over 3500 hours of staff time have been expended to study the area and develop the plan.

Review and Tabulate Historic Records

Staff in both the Denver and Pueblo offices were assigned to review, tabulate and analyze all known water rights. This included: reviewing all the known decrees entered by the water court and various district courts; retrieving and tabulating all well permits; tabulating all known diversion and streamflow records; and reviewing previous administrative orders and decisions. Unfortunately, the documents which had to be reviewed were often not complete; had discrepancies in legal descriptions, acres irrigated or other factual information; and current water use practices as viewed from aerial photos or field trips differs from decreed or well permit uses. One of the major tasks was to develop an integrated list of water rights which cross-referenced well permits and which could be sorted in order of priority. That tabulation is discussed further in Chapter VIII and appears as Tables 1 through 3.

Field Work

Several field trips were made to evaluate the area, current water usage, hydrologic and geologic conditions and to interview water users. Geologists spent several days in the field verifying Pierre Shale outcrops and supplementing the published surficial geologic maps. The well drilling inspectors selected approximately 85 wells for which depth to water level measurements were made during October, November and December of 1988 and January and February of 1989. Hydrographers selected 20 locations on streams for which weekly observations or measurements were taken since September 24, 1988. A plane was rented for aerial reconnaissance of irrigated acreages along Horse Creek, Little Horse Creek, Steel Fork and Breckenridge Creek. A videotape was made throughout the flight and 56 aerial photos were taken.

As a result of the field work, a much better understanding has been gained of the geology, hydrology, location of existing water rights, and both historic and current water use practices. The brief period of study has indicated the need for water measurement devices to record diversions and streamflows and an observation well network is needed to monitor fluctuations in the ground water levels. Additional field investigations are needed during the irrigation season to determine whether current water usage is in compliance with the decrees and well permits.

Analyses

Several in-depth analyses have been performed which are the basis for the recommended administrative plan. After some review of geologic and hydrologic data, a decision was made on an original study area. The area included data for wells outside the topographic drainage basin of Horse Creek and its tributaries. A description of the logic supporting the selection of the area or basin in which this plan applies can be found in Chapter 4.

The most time consuming and critical analysis was to identify the administrable water rights. The tabulations, Tables 1 through 3, have been sorted by computer in several different orders and will allow one to identify who has the senior right, which rights are in close proximity to each other and what is the authorized use of the right. The rights in the tabulation have been located on maps and could thus be field checked for compliance with the decrees or well permits.

Previously published geologic and hydrologic reports were reviewed and a decision was made to develop detailed bedrock and water table contour maps from all data available to this office. The discussion of geologic and hydrologic interpretation can be found in Chapters 5 and 6. The geologic and hydrologic analyses included the preparation of geologic cross-sections, analysis of ground water fluctuation data and interpretation of the impact of ground water pumping on surface water flows. Variations in streamflows over the past five months was considered in the analyses of ground and surface water interaction to develop an understanding of how the ground and surface water systems impact each other.

A water budget analysis was attempted. Chapters 9 and 10 describe the difficulties in developing data to estimate the watershed's safe yield. The collection over the next 12 to 18 months of additional data will allow calculation of the average annual safe yield of the basin. Once the safe yield is estimated, an administration plan to utilize the total water resources of the basin can be developed.

CHAPTER 4

GEOGRAPHY

Topography and Drainage

The study area lies within the Colorado Piedmont Section of the Great Plains physiographic province. The northern part of Horse Creek Basin consists of narrow, nearly parallel stream valley lowlands separated by flat to gently rolling interstream divides. The streams merge in the southern part of the basin (see Figure 1) and ultimately form two wide and nearly featureless valley systems: Horse Creek and Breckenridge Creek. Stream gradients range from 50 to 60 feet per mile in the northern part of the area to 10 to 20 feet per mile in the southern part.

Local topographic relief in major drainages ranges between 100 and 200 feet, whereas relief in minor drainages is 50 feet or less. The most prominent topographic feature of the study area is a significant, generally south and southeast facing escarpment or outcrop of the Pierre Shale, hereafter called the Pierre escarpment (see Figure 1). The Pierre escarpment generally ranges between 100 and 150 feet in height but approaches 200 feet where State Highway 94 crosses Horse Creek west of Punkin Center. The escarpment was developed by water erosion and is due to the shale having a greater resistance to erosion than the overlying Nussbaum. This escarpment corresponds to several prominent landmarks in the basin including Antelope Mesa located in Section 33, Township 19S, Range 58W; Walker Point located in Section 30, Township 17S, Range 57W and it also coincides with the valley walls of Steels Fork, Little Horse Creek and Horse Creek throughout the center of the basin.

The maximum topographic relief in the basin is about 2650 feet. The land surface elevation on the northwest side of the basin, 4 miles south of Calhan, is approximately 7000 feet. The land surface elevation of the Horse Creek streambed northeast of Lake Henry is about 4350 feet.

The Horse Creek Basin drains toward the south and southeast and flows into the Arkansas River just west of Las Animas. The principal streams are Horse Creek, Little Horse Creek, Steels Fork, and Breckenridge Creek. These streams originate in highlands which separate the Horse Creek Basin from the northeastward flowing Big Sandy Creek and southward trending streams of Black Squirrel Creek (see Figure 1).

Horse Creek, Little Horse Creek, Steels Fork, and their tributaries are closely spaced, have long, nearly featureless drainage divides and flow in a southeastward direction. About seven miles south of Punkin Center, Horse Creek turns toward the south. Little Horse Creek and Steels Fork flow into Horse Creek about 10 miles farther south. Upstream of these confluences, the channels of Little Horse Creek and Steels Fork are poorly defined and nearly grassed over.

Breckenridge Creek flows into Horse Creek about 3 miles northeast of Lake Henry which is about 2 miles upstream of the southern boundary of the basin. Breckenridge Creek drains the area south of the Steels Fork subbasin. The principal tributary of Breckenridge Creek is Pond Creek which is also called Dead Horse Creek in its lower reaches. Pond Creek is nearly twice as long as Breckenridge Creek and originates in the sandy flatland near the town of Yoder.

A large number of springs and seeps occur along the top of the Pierre escarpment. It is these springs and seeps which cause Horse Creek, Little Horse Creek, Steels Fork, and Cramer Creek (a tributary of Breckenridge Creek) to have reaches with perennial flow. The streams are perennial because of the continuous spring flow which accumulates in the stream channels cut into the impermeable Pierre Shale. There are no significant alluvial deposits throughout these perennial flow reaches. For Horse Creek, Little Horse Creek and Steels Fork the perennial reaches range from 6 to 12 miles in length.

Breckenridge Creek has about 7 miles of perennial flow in a reach from its confluence with Lone Tree Creek, located in Section 28, Township 19S, Range 57W, downstream to its confluence with Horse Creek. This reach is perennial because the Pierre Shale bedrock channel narrows and the alluvium thins. This forces the ground water to converge and flow to the surface.

Throughout the perennial flow reaches there is high evapotranspiration from native vegetation, pasture grasses and hay meadows. In the fall, following a killing frost this evapotranspiration is reduced and streamflows increase which cause surface flows to extend further downstream. For example, in most years, Steels Fork has had live flow during the November to May period as far downstream as the Brooks Ditch headgate located in Section 35, Township 16S, Range 57W. In the spring when evapotranspiration increases, the streamflows decrease and the length of live flow recedes upstream. Similar phenomena occur annually below the perennial stream reaches for all the streams mentioned above.

With the exception of the previously described perennial flow reaches, the remainder of the stream reaches have intermittent flows. The period of flow coincides with either precipitation runoff following thunderstorms, snowmelt or seasonally fluctuating baseflows as described above. Above the perennial flow reaches associated with the Pierre escarpment all the streams are intermittent.

Climate

The Horse Creek Basin is typical of the continental, semiarid plains regions -- the climate is relatively uniform from place to place, sunshine is abundant, rainfall is generally light, wind movement ranges from low to moderately high, and the daily range in temperature is large.

The mean annual precipitation ranges from a high of about 16 inches at the upper end of the basin near Calhan to a low of 10.76 inches at Ordway. Precipitation stations located in or near the basin include Rush 4N, Karval and Ordway. The upper third of the basin has a mean annual precipitation rate in excess of 12 inches per year while the lower two thirds has less than 12 inches per year. Contoured maps from the U.S. Department of Commerce (1956) and from the Colorado Climate Center (1984) reveal that for the entire basin about 9.0 inches occur between May-September and about 3.5 inches occur between October-April. Summer precipitation occurs as unevenly distributed thunderstorms. Such uneven distribution of precipitation results in some areas experiencing extended dry periods. Winter snowfall is commonly accompanied by wind leaving vast snow-free areas with drifting along fence lines, depressions and obstructions. Doesken, McKee, and Richter (1984) suggest that precipitation in the southern half of the basin has decreased by as much as one inch since the 1960's.

Average daily temperatures in the basin range from highs of 90°F in July to lows of 12°F in January. Daily high temperatures often exceed 100°F in the lower part of the basin for a number of days each summer. Killing frosts usually occur in October throughout the basin.

Agricultural Practices and Economic Importance

The economy of the basin is based upon dryland farming, cattle ranching, and irrigated farming. Dryland farming and cattle ranching utilize more than 50 percent of the basin's land area. Dryland crops are winter wheat and drought resistant grains such as milo. Cattle ranching is widespread, but due to the basin's semiarid character, growth and reproduction of natural grasses is slow and extensive range is required to supply sufficient forage for existing herds.

Irrigated crops include alfalfa, native hay, pasture, corn, small grains and a significant amount of turf grass or sod. The alfalfa, hay and grains are utilized by the area ranchers to feed their livestock during the winter months. The turf grass or sod is cut and shipped out of the basin for landscaping in the Colorado Springs and Denver metropolitan areas. Turf grass requires more irrigation than even alfalfa.

The turf grass farms are located near Rush with irrigation from large capacity wells constructed into the Nussbaum aquifer. Many of the farms use sprinkler irrigation including center pivot systems.

Surface water is diverted from the perennial streams to irrigate alfalfa and native hay in the narrow valleys of Horse Creek, Little Horse Creek, Steels Fork and Cramer Creek. In this same area there is extensive subirrigation of native hay and pasture due to the flow from springs and seeps out of the Nussbaum aquifer.

In the lower part of the basin the early surface irrigation was supplemented by the use of wells producing from the stream alluvium. A more complete description of how irrigation developed can be found in Chapter 8. The area's economy is dependent upon irrigation to produce crops for sale or use as winter feed for the cattle ranches.

The area is served by a system of graveled and paved county roads and

State Highways 71 and 94. The towns of Yoder and Rush support small businesses with agricultural support functions such as equipment repair and machine shops.

<u>Selection of Basin Boundaries</u>

The State Engineer has considered geology, topography, hydrology and location of existing water rights in selecting the boundaries of the basin for this administrative plan. The court's decision in Cases W-2545 and W-3890 and the ruling on March 12, 1987 in Case No. 86CW91 states that administration of the Preisser wells was not necessary to protect the water rights on the mainstem of the Arkansas River. A basin was selected so that it could be administered without having to consider the impact of rights in the basin on the senior water rights of the Arkansas mainstem.

Because of the location of the Box Spring water rights on Horse Creek which are some of the most senior, it was necessary to consider the basin as being all that area which could produce runoff at their point of diversion. This suggested the basin should include all the land inside the topographic divide of Horse Creek, Little Horse Creek and Steels Fork.

A study of the Breckenridge drainage including all its tributaries was made. The water rights in that basin are tabulated in Tables 1, 2 and 3 and these are displayed as the straight line diagram of Plate 13. Because of the similarity in geology, hydrology and location of water rights to those in the Horse Creek Basin, it was decided to include Breckenridge Creek in this administrative plan.

The bedrock contour map and historic water level map, Plates 1 and 3 respectively, were compared with a topographic map. The bedrock and water table divides for the Horse Creek and Breckenridge Creek drainages coincided with the topographic divide of those two basins. This supports selection of the topographic divide as the boundary for the administrative plan because there would be no impact by shallow wells or surface diversions outside the topographic divide on water rights inside the Horse Creek-Breckenridge Creek drainages. Similarly, the administration of rights inside the topographic divide would not have impact on any other rights except across the downstream boundary.

The lower boundary for this administrative plan was chosen as the south side of Sections 26, 27, 28 and 29, Township 20S, Range 56W, 6th P.M. This boundary was chosen because:

- It is downstream of the confluence of Breckenridge Creek with Horse Creek.

- The bedrock channel associated with the two drainages narrows at this location but expands further downstream.

- Horse Creek flows are infrequent and occur only as a result of summer thunderstorm runoff.

- Ground water outflow is nearly constant.
- Diversions from the Arkansas River through the Colorado Canal-Lake Henry system are applied below this boundary, thus no water from the Arkansas River is used in the basin.
- The closest rights to be administered in this plan are over 4 miles upstream of the boundary.

CHAPTER 5

GEOLOGY

Previous Investigations and Field Work

The geology of the southern part of the area is briefly described by Palton (1924) and Topelman (1924). Dane, Pierce, and Reeside (1937) described the region's Cretaceous rocks. The northernmost part of the basin was studied by McLaughlin (1946). The Colorado Division of Water Resources conducted a reconnaissance study of the area surrounding the confluence of Steels Fork with Horse Creek in 1968, Romero (1988). Brogden (1973) described hydrogeologic characteristics of parts of Steels Fork and Little Horse Creek drainages. Regional characteristics of the Denver Basin aquifers were first described by Romero (1976). The geology of the Lamar Quadrangle was published in 1976 (Sharps), and that of the Pueblo 1° x 2° Quadrangle in 1978 (Scott). A geohydrologic investigation of the Lazy T Milliron Ranch was conducted by Resource Consultants in 1978. Robson (1981) and Van Slyke (1988) published updated versions of Denver Basin bedrock aquifer studies. Hydrokinetics, Incorporated conducted a water well evaluation study for Travelers Insurance Company in 1987. There has been extensive soil survey mapping by the U.S. Department of Agriculture, Soil Conservation Service. Geologic and hydrologic investigations including field geologic investigations, streamflow measurements, establishment of a water-level monitoring network of about 85 wells, an aerial survey, interview of water right owners, and extensive water rights research were completed during the study period.

General and Structural Geology

Geologic formations outcropping or subcropping in Upper Horse Creek Basin range in age from Recent to late Cretaceous. All of the formations are of sedimentary origin, and all but one are known to yield limited or moderate quantities of water to wells. The formations can be subdivided into two groups: 1) unconsolidated or surficial formations, and 2) bedrock formations. The surficial formations are composed of gravel, sand, and clay eroded from pre-existing sedimentary and igneous rocks. Regional slope or dip of these sediments is toward the south and southeast. They make an unconformable contact with the underlying bedrock formations.

The bedrock formations are composed of poorly to moderately consolidated sandstones, siltstones, and shales of continental, transitional, and marine origin. Figure 2 is a general geologic map showing outcrops and subcrops of bedrock formations, and Plate 9 is a longitudinal, northwest-southwest cross-section of the basin. The Dawson, Denver, Arapahoe, Laramie, and Laramie-Fox Hills bedrock strata are members of the Denver Basin Bedrock Aquifer System. The dip of these strata and the underlying Pierre Shale is toward the northwest.

The thickness, physical character and water yielding properties of Horse Creek's stratigraphic units are summarized in Table 4.

Description of Geologic Formations

Pierre Shale

The Pierre Shale directly underlies the Laramie-Fox Hills Aquifer in the northern one-third of Horse Creek Basin and is the bedrock surface for the southern two-thirds (Figure 2 and Plate 9). It consists of about 4000 feet of dark to brownish gray shale with thin interbeds of sandstone, siltstone, and limestone (Sharps 1976). Outcrop colors range from dark yellowish orange to moderate and dusky brown. There are at least three distinctive horizons within the Pierre Shale. In Section 18, Township 14 South, Range 57 West, septaria concretions and gypsiferous shale near the middle of the Pierre Shale, as described by Toepelman (1924), were observed. Numerous small, conical hills known as the Pinnacles or Tepee Buttes exist in Section 30, Township 18 South, Range 55 West. These hills consist of shale beds capped by fossiliferous and erosion resistant limestone. Sharps (1976) places these beds in the lower Pierre. A third lower Pierre horizon, consisting of dark to dusky brown shale containing abundant mollusk fossils and ironstone concretions was observed in Section 4, Township 20 South, Range 58 West.

In general, outcrops of the Pierre occur intermittently along the banks of major streams and in the central part of the basin along the Pierre escarpment. This formation is considered to be impermeable and prevents the downward movement of water. Only from sandy lenses in the upper 500 feet of the formation located in the extreme northwest part of the basin has ground water been obtained for stock wells.

Denver Basin Bedrock Aquifers

Dawson Aquifer--The basal part of the Dawson Aquifer outcrops and subcrops along the northern and western margins of the basin, Figure 2. Excellent exposures of varicolored clay occur at the Paint Mine, south of Calhan and other exposures form the tops of low hills along the Calhan Highway. At the Paint Mine, colors are white, pink, pale to dark yellowish orange with streaks of grayish purple, dusky red, and reddish brown. Van Slyke (1988) and Robson (1981) describe the Dawson in more detail. The Dawson in Horse Creek Basin is estimated to be less than 250 feet thick and thins rapidly toward its contact with the underlying Denver Aquifer. The Dawson and underlying bedrock aquifers are truncated by erosion and for the most part covered by younger, unconsolidated alluvial and Eolian deposits or soil.

Denver Aquifer--The Denver Aquifer subcrops over approximately 60 square miles in the northern part of Horse Creek Basin, Figure 2. The aquifer consists of a series of interbedded clay-shale, claystone, siltstone, and sandstone lenses in which fossilized plant remains and coal are common (Van Slyke 1988). Its most distinctive characteristics are its predominantly fine-grained character and olive, green, and brown coloration. The only Denver Aquifer exposure observed during the course of this investigation was a road cut outcrop along the Calhan Highway in the southeast quarter of Section 8, T.3S., R.6 West. Here, pale orange to dark yellowish orange, fine to medium grained sandstone with concretions, and soft deformational features are covered by only a few inches of soil. The bedding and structural features are consistent with deposition in a fluvial environment. The thickness of the Denver Aquifer in the Horse Creek Basin ranges from a featheredge to about 600 feet.

Arapahoe Aquifer--The Arapahoe Aquifer subcrops in the Horse Creek Basin as a three to four mile wide strip, Figure 2, and extends northwestward under the Denver Aquifer. Throughout most of the Denver Basin, the Arapahoe Aquifer consists of a series of interbedded conglomerates, sandstones, siltstones, and clay shales (Van Slyke 1988). Deeply buried Arapahoe strata are normally gray to olive gray and greenish olive along the southern boundary of the Denver Basin. In the Horse Creek Basin, thickness of the Arapahoe ranges from a featheredge to about 450 feet.

Laramie Formation--The Laramie Formation subcrops in a one to four mile wide strip across the northwest part of the Horse Creek Basin, Figure 2. The Laramie forms a hydrologic barrier between the overlying Arapahoe Aquifer and the underlying Laramie-Fox Hills Aquifer. Strata of the Laramie consist of clay and shale with subordinate sand lenses and coal, the latter being more common in the lower half of the formation. Thickness of the formation ranges from a featheredge to about 200 feet.

Laramie-Fox Hills Aquifer--The Laramie-Fox Hills Aquifer also subcrops in a three to four mile wide strip across the Horse Creek Basin, Figure 2. The Laramie-Fox Hills consists of light gray to light bluish gray very fine to medium grained sandstone and sandy siltstone with interbedded shale. Siltstone and shale predominate the lower half of the aquifer. Average thickness is 300 feet which thins to a featheredge along its lower boundary. Van Slyke (1986) discusses the Denver Basin Aquifers in more detail.

Nussbaum Alluvium

The older Nussbaum Alluvium of Pleistocene age is found throughout highlands of the basin (Sharps 1976 and Scott 1978). It is commonly covered by Eolian deposits and/or a thin veneer of soil. The best exposures of the Nussbaum are in the northern half of the basin in stream cuts. The most conspicuous topographical form of the Nussbaum is where it forms the cap of the Pierre escarpment. It is composed of unconsolidated cobbley gravel, sand, and silty sand with a slight admixture of clay (Patton 1928). Sharps (1976) attributes the depositional environment of the Nussbaum to a broad alluvial fan not related to the present drainage. Cross bedding and fining-upward sequences were observed in Nussbaum outcrops in a gravel pit in Section 32, Township 18 South, Range 58 West, and Section 7, Township 14 South, Range 57 West. This is indicative of fan channel systems or of marginal fluvial channels reworking older fan deposits. The color of the Nussbaum deposits ranges from pale reddish brown to light brown and dark yellowish orange. Thickness of the Nussbaum ranges from a featheredge to 160 feet (the boundary between the Nussbaum and overlying deposits is difficult to distinguish in drillers logs). The thickest Nussbaum is located in Townships 13 and 14 South and Ranges 58 and 59 West of the 6th P.M.

Alluvium, Slope Wash, and Eolian Deposits

Alluvial deposits of recent age are present throughout the Horse Creek drainages. Deposits within present stream channels consist of fine to course sand and fine to medium gravel. The width of these channel deposits vary from about 200 feet in Horse Creek valley in the southern part of the basin to generally less than 50 feet in the northern part of the basin. Horse and Little Horse Creeks maintain a uniform width over considerable distances. The Horse Creek channel, only 1 1/4 mile downstream from its origin, is 100 feet wide. Color of the deposits varies from dark yellowish gray to yellowish tan.

Floodplain deposits occur in most drainages downstream of the Pierre escarpment. These deposits consist of sand and gravel interbedded with silt -- the latter a result of low-energy stream deposition. Floodplain width varies from 100 to 300 feet near well developed streams in the northern part of the basin and increase to 3/4 mile in the southern part of the basin. Colors of these deposits are generally dark yellowish gray to yellowish tan but are frequently grayish orange to pale yellowish brown where sheet wash of Pierre Shale has occurred. There has been no attempt by the authors to further subdivide the floodplain deposits.

The combined thickness of the channel and floodplain deposits ranges from a featheredge to about 60 feet. Thicker deposits occur along Horse Creek in the north-central part of the basin, southwest of Punkin Center.

Slope wash deposits flank most of the basins flood plains and are most prominent in the southern half of the basin. They consist primarily of silt, sand, and gravel from older Quaternary deposits mantling the Pierre Shale, and interbeds of silt and clay from the Pierre Shale itself. Gravel, fragments of concretions, fossils and fossil fragments, and other rock fragments also occur in these deposits. The most prominent slope wash deposits are those which extend from the base of the Pierre Escarpment. Thickness of the slope wash deposits is estimated to range between a featheredge and 10 to 20 feet. Color varies with the parent material; various shades of red to reddish yellow where Quaternary parent material predominates to brownish yellow to yellowish brown where Pierre Shale material is significant.

Windblown sand, silt and clay referred to as Eolian deposits cover at least 50 percent of the basin. Sharps (1976) mapped these deposits along most of the Horse Creek valley, locally in the Breckenridge-Pond Creek valley, on the highlands and in other minor drainage areas. Grain size ranges from very fine to medium and color ranges from yellow brown to tan. The sand is probably derived from winnowing of alluvial deposits. Generally, it is stabilized by vegetation, although roadcuts and overgrazing have allowed the occurrence of some drifting. Loess, windblown silt, occurs in the highlands along the eastern boundary of the Horse Creek Basin and along the divide between the Horse Creek and Pond Creek subbasin in the south-central part of the study area. According to Sharps (1976), the deposits are principally equivalent to the Peoria Loess of Kansas and Nebraska.

Another Pleistocene alluvium present in the basin is a small isolated remnant of the Rocky Flats Alluvium located about eight miles north of Ordway which has been mapped by Sharps (1976). The deposits consist of cobbley gravel and silty sand, with its basal part generally cemented by caliche. It is of minor importance in the basin.

Soil Mantle

The soils developed in the Horse Creek Basin reflect the composition of the underlying parent material. The soils developed over the Pierre Shale have greater clay contents than soils developed over alluvium and other formations. The extensive history of erosion and redeposition in this area since Tertiary time has provided a variety of parent materials for soil development. Variations in the soil characteristics result from a number of factors, including the initial composition and texture of the parent material, the topography and exposure of the site, and the amount of water available at the site.

In the northern third of the study area, the soils are predominantly sandy loam to loamy sand of the Truckton, Blakeland, Bresser soil series (Larsen 1981). These are moderate to well-drained soils derived from the weathering of alluviums and sedimentary rocks (Larsen 1981). The Olney and Vona series occur primarily in the central and southern part of the report area. These soils are deep, well drained sandy loams developed upon sandy calcareous sedimentary debris.

Other soil series present in the southern third of the study area include the Ordway, Limon, Deertrail, Stoneham, Baca, and Tivoli-Dune all on upland areas, and the Bankard, Glenberg, and Las soils are present in the valleys. The Deertrail-Stoneham-Baca soils consist of deep clay loam soils developed upon slope wash material transported from upland areas. The soils are commonly alkaline and occasionally calcareous. They absorb water easily. The Ordway-Limon soils consist of deep silty clay to clay soils developed upon the Pierre Shale (Larsen 1968), contain slight amounts of gypsum, are poorly drained, and have low permeabilities. The Tivoli-Dune soils are deep sandy soils developed on sand dunes and alluvium and are extremely permeable and well drained. Surface drainages do not generally develop on these soils, and they are very susceptible to wind erosion.

The Bankard-Glenberg-Las soils are developed upon the floodplain and terrace deposits of Horse Creek. They range from loamy sand and sandy loam to clay loam. The permeability varies with soil type as do drainage conditions and the soils are frequently calcareous and saline.

All of these soils are highly susceptible to erosion. They primarily support rangeland grass plant cover, but cottonwood and salt cedar are common in some stream reaches.

Configuration of the Bedrock Surface

Sometime after deposition of the Nussbaum Alluvium, the area was subjected to an erosion cycle which resulted in gradual headward erosion of

Horse Creek and its tributaries, removal of the Nussbaum, and formation of the Pierre escarpment. Below this escarpment comparison of bedrock contours with land surface contours reveal nearly identical configuration along most of Horse and Little Horse Creeks and Steels Fork. This characteristic is due to the thin veneer of unconsolidated deposits which overlie the bedrock surface. Thicknesses of less than 30 feet are common, and thicknesses of zero to only a few inches occur along much of the Pierre Escarpment.

Plate 1 is a map showing the configuration of the erosion surface underlying Horse Creek Basin's unconsolidated deposits. In the northern part of the basin the erosion surface is cut into the Dawson, Denver, Arapahoe, Laramie, and Laramie-Fox Hills strata (Plate 2). Throughout the lower two-thirds of the basin the elevation of the top of the Pierre Shale is displayed on Plate 1.

Thickness of the unconsolidated deposits, at any point, can be estimated by subtracting the altitude of the bedrock surface, Plate 1, from the altitude of the land surface or by using well drillers logs.

CHAPTER 6

GROUND WATER

Occurrence and Movement

The Pierre Escarpment, shown on Figure 1, separates the shallow ground waters in the unconsolidated materials into two distinctly separated aquifers: the Nussbaum-Eolian sand above the escarpment and the alluvial-slope wash aquifer below the escarpment, Figure 2. Outflow from the upper aquifer occurs as springs and seeps which flow down the streams and recharges the lower aquifer. Because of this relationship, pumping from the upper aquifer can reduce discharge from the upper aquifer, thus impacting the lower aquifer. Pumping from the lower aquifer cannot have any impact on the upper aquifer.

Nussbaum-Eolian Sand

The Nussbaum alluvium was deposited during the Pleistocene Era upon an unconformity eroded into the Denver Basin bedrock aquifers and the Pierre Shale. The bedrock map (Plate 1) depicts the configuration of the bedrock unconformity which slopes to the southeast and has localized erosional channels.

The windblown sands referred to here as Eolian sand were deposited on top of the Nussbaum and are generally considered to be of recent Pleistocene origin. It is difficult to differentiate between the Nussbaum and the Eolian sands and both may be saturated and serve as a single producing aquifer.

The maximum combined thickness of the Nussbaum-Eolian sand deposits exceeds 120 feet in Township 14S and Ranges 58 and 59W. During the early 1960's there was as much as 80 feet of saturated thickness in that same area, but it has been reduced to only 30 or 35 feet in 1988. Elsewhere the thickness of the combined formations decreases to a featheredge near the Pierre escarpment and around the north and west sides of the basin. The formations generally have some saturation near the Pierre escarpment but may be completely dry along the north and west boundaries. The amount of saturation can be determined by subtracting the bedrock elevation, Plate 1, from the water table elevation depicted on Plates 3 and 4 or by referring to well logs.

Water in the Nussbaum-Eolian sand aquifer generally moves toward the southeast. Because of the variation in bedrock elevation and the non-homogeneity of the aquifer there are localized flow gradients. Flow in the aquifers moves at right angles to the water table contour lines drawn on Plates 3 and 4. Outflow from the formation appears as springs or seeps along the Nussbaum-Pierre Shale contact. In some instances there may not be visible springs or seeps, but the water is taken up by the overlying soil mantle where it either supports vegetative growth or evaporates. Throughout much of the basin there is a distinct change in vegetative species and plant growth above and below that contact which is related to the additional moisture.

The hydraulic conductivity of the Nussbaum-Eolian sand is estimated to be 1,600 gallons per day per foot squared (214.4 ft./day) considering the data from Wilson (1965), Erker (1965), McGovern (1966) and Hydrokinetics (1987). The specific yield is estimated to be 18 percent.

Denver Basin Bedrock Aquifers

Plate 2 and Figure 2 show the approximate geologic contacts of the Denver Basin bedrock formations in the Horse Creek Basin, and Plates 6, 7, and 8 show the elevation of the potentiometric surface for the Denver, Arapahoe and Laramie-Fox Hills aquifers respectively. The potentiometric contours for each aquifer are based upon a combination of both historic and recent water level data, historic data from the State Engineer's files and recent data from water level measurements taken during the fall of 1988 and winter of 1988-1989. The potentiometric surfaces slope toward the southeast and indicate that water from those formations will discharge into the overlying Nussbaum-Eolian sand deposits. This phenomenon is supported by maps prepared by Romero (1976), Robson and Romero (1981), and Robson and others (1981). Estimates of the quantity of water discharged from the bedrock aquifers into the alluvium are presented later in this chapter.

Depth to water in the Denver Basin bedrock aquifers ranges from 100 to well over 200 feet depending upon the distance of the well from the subcrop area, and perforated zone of the well. Generally, the water yielding zones are under artesian pressure, and water will rise to a point higher than where it was first encountered.

The estimated hydraulic conductivity of the Denver, Arapahoe, and Laramie-Fox Hills aquifers is 1.0, 0.5, and 0.5 feet per day, respectively; or in terms of gallons per day per square foot is 7.48, 3.74, and 3.74, respectively. Robson (1983) discusses Denver Basin aquifer coefficients in more detail. Colorado Division of Water Resources estimates of specific yield are: Denver Aquifer - 17%, Arapahoe Aquifer - 17%, and Laramie-Fox Hills Aquifer - 15%.

Division of Water Resources' files reveal that 51 registered water wells are completed in the Pierre Shale. Most of these are located within three or four miles of the Laramie-Fox Hills Aquifer-Pierre Shale boundary. The wells are completed in thin sandstones and siltstones, located 100 to 500 feet below the Laramie-Fox Hills Aquifer. All of the Pierre wells are utilized for domestic or stock purposes and yield less than 15 gallons per minute.

Recent Alluvial and Slope Wash Aquifers

Downstream from the Pierre escarpment the Pierre erosion channel is filled with recent alluvium (Figure 2). This alluvium consists of some gravels, sands, silts and clays which were derived from erosion higher in the basin of the Nussbaum and the Denver Basin Aquifers. Generally there is more clay in this alluvium than in the Nussbaum. The alluvium merges or is overlain by slope wash materials closer to the Pierre escarpment (Figure 2). It is difficult to separate the slope wash from the alluvium and where saturated they act as a single aquifer.

As discussed in Chapters 4 and 5 there does not appear to be any significant alluvial deposits in those reaches of Horse and Little Horse Creeks, Steels Fork or Cramer Creek where the streams are perennial. Only when the stream gradient flattens does deposition of alluvial materials begin and the deposition thickness increases downstream. The maximum thickness of this alluvial deposit may reach 60 feet near the confluence of Steels Fork with Horse Creek and at another location along Horse Creek in Sections 1 and 2, Township 15S, Range 57W. Only a portion of the alluvium and slope wash are saturated. The maximum saturated thickness is 30-35 feet where the alluvium is thickest. The aquifer thickness varies between 25 and 35 feet over a significant area but decreases in thickness to a featheredge near the Pierre escarpment and along the topographic divide on the east and south sides of the basin. Throughout much of the alluvium-slope wash aquifer the saturated thickness is less than 15 feet which can support livestock or domestic wells but cannot supply enough water for irrigation.

The direction of movement of water in this aquifer is generally toward the southeast as shown on Plates 3 and 4. There are localized gradients which cause flows to concentrate in the deeper alluvium. Generally the depth to water is 10 feet or greater except for the high water table area along Horse Creek upstream of the Box Springs diversion in Section 20, Township 18S, Range 56W and the reach of Breckenridge Creek between its confluences with Lone Tree Creek and Horse Creek.

The hydraulic conductivity of this aquifer is also estimated to be 1,600 gallons per day per foot squared with a specific yield of 18 percent.

<u>Recharge and Discharge</u>

The principal source of recharge is the deep percolation of precipitation through the soil mantle into the underlying aquifer. In this basin there is extreme variability in precipitation in both time and space. For this study it was assumed that only 3 percent of the mean annual precipitation, 12.5 inches per year, is considered to be natural recharge. The area of the basin upstream of the south boundary totals 1070 square miles, 684,800 acres. The estimated recharge is 21,400 acre-feet per year. Further analyses are needed to refine this estimate and to calculate the amount of recharge to each aquifer.

As mentioned in Chapter 5, there are outflows from the Denver Basin bedrock aquifers into the Nussbaum alluvium. Darcy flow calculations were made to estimate the outflow from the Denver, Arapahoe and Laramie-Fox Hills aquifers. The potentiometric head maps, Plates 6, 7 and 8, were drawn using static water level data from the well completion reports on file in the State Engineer's office. Many of those wells only partially penetrate the respective aquifer and are perforated to produce from only a portion of the total aquifer.

The annual outflows from the Denver Basin aquifers to the Nussbaum-Eolian were estimated to be 590 acre-feet from the Denver aquifer, 550 acre-feet from the Arapahoe aquifer and 1170 acre-feet from the Laramie-Fox Hills, totaling

2310 acre-feet. Further studies are needed to confirm this estimate and to identify the location of the outflow. The Laramie-Fox Hills appears to contribute about 50 percent of the outflow.

Natural recharge to the lower alluvial-slope wash aquifer also includes a significant contribution from seepage of flows out of the bottom of the stream bed. The description of how this seepage occurs and how it saturates the alluvium before the stream advances downstream can be found in Chapter 7. Estimates for the amount of recharge so occurring during the 1988-89 period have not been made stream by stream and reach by reach but will be significant. For example, seepage of 5 cfs for a three-month period would be about 900 acre-feet. It is the reduction of stream base flows downstream of the Pierre escarpment which have reduced the natural recharge to the alluvial-slope wash aquifer.

Deep percolation of irrigation return flows does recharge the aquifers. Because of the shortage of irrigation water and use of sprinklers for the irrigation wells pumping from the Nussbaum-Eolian aquifer, the return flow recharge to that aquifer is expected to be very small or insignificant. Irrigation wells pumping from the alluvial-slope wash aquifer are used for gravity irrigation on the Reid, Lazy T-Milliron and Box Springs properties. The recharge from deep percolation of that water might be significant. Studies are needed to estimate the amount and location of recharge resulting from deep percolation of irrigation water.

Discharge from the Nussbaum-Eolian aquifers consists of spring and seep outflow, direct evaporation or transpiration in areas having shallow water tables and the withdrawal by pumping. Data are not yet available to allow calculation of each of these quantities. Due to the historic water level declines (Plate 5 and Figures 3A-3E) it is known that the discharge is exceeding the recharge.

For the alluvial-slope wash aquifer the discharge consists of evaporation or transpiration from areas having a shallow depth to the water table, pumping withdrawals and ground water outflow across the southern boundary of the basin. More data are needed to quantify the discharges. The decline in water levels, Plate 5 and the Reid hydrograph (Figure 3E) show that there are localized areas where discharge is exceeding recharge.

<u>Ground Water Usage</u>

The State Engineer's records show that approximately 890 wells have been constructed within the basin of which 300 withdraw water from the Denver Basin bedrock aquifers. Approximately 220 of these were utilized for irrigation, five supply municipalities outside the basin, and the remainder are utilized for domestic or livestock purposes. Well discharges range from 2-5 gallons per minute for livestock wells to 500-1000 gallons per minute for the irrigation wells. At least one irrigation well was decreed for a 2000 gallons per minute pumping rate. Data are not available to identify which wells are still in use, how they are being used or how much they are pumping. Field investigations in 1989 will provide some of that data.

Historic Ground Water Changes

An effort has been made to identify the predevelopment state of the ground water aquifers. Plate 3 shows the historic water level contours for the two alluvial aquifers. This map was prepared using the reported static water levels from the well completion or late registration reports filed with the State Engineer's office. Other things considered in preparing the map included both land surface and bedrock elevations, location of springs and outcrops of the Pierre Shale. The static water level measurements from these reports were made over an extended period of time and preference was given to the earliest measurement where there were discrepancies.

Analysis of the direction of ground water flow in the Nussbaum-Eolian aquifer shows that there was flow toward Steels Fork, Little Horse Creek and Horse Creek and this corresponds to the location of springs on the U.S. Geological Survey topographic maps. Several cross-sections, A-A', B-B', C-C' and D-D' have been prepared as Plates 10, 11, 12 and 16. The location of the cross-sections is shown on Plate 4. Darcy's law was used to calculate the amount of ground water underflow through each cross-section and the calculations are tabulated in Table 5.

To evaluate how the aquifer conditions have changed, a decision was made to collect recent static water level data from wells throughout the Horse Creek drainage but not the Breckenridge drainage. A large number of wells were visited in the field to see if it was possible to measure static water levels. Approximately 85 of these wells were selected in October 1988 and a monthly measurement program was started. Office research was undertaken to identify the well permits for these wells and to locate any other historic water level data. Some data were obtained from the following firms who have worked in the basin: HRS Water Consultants, Inc.; Jehn and Wood Associates; Bishop-Brogden Associates, Inc.; Resource Consultants, Inc.; and Gopher State Well & Pump.

A map of the static water levels representing the fall of 1988 has been prepared as Plate 4. This map was used to obtain data for the cross-sections A-A', B-B', C-C' and D-D' to illustrate the 1988 levels. Darcy calculations were also made, see Table 5. A water level change map from the predevelopment period to the fall of 1988 was prepared as Plate 5.

Referring to Plate 5 there has been a significant lowering of the water level in the Nussbaum-Eolian aquifer in Township 13S, Range 59W; Township 14S, Range 58 and 59W; and Township 15S, Range 58W. This area of decline coincides with the large number of irrigation wells (see Plate 14) which are pumping from this buried channel. There is another area of decline around Section 22, Township 14S, Range 58W which coincides with more irrigation wells including those belonging to Mr. Preisser.

Referring to Plate 5, there are other localized areas of water level decline in excess of five feet in the lower alluvial-slope wash aquifer. These areas surround concentrations of irrigation wells and reflect that withdrawal by pumping is exceeding the natural recharge. The greater than

20-foot decline center located in Township 16S, Range 57W surrounds the wells owned by Logan, Kuester, Reid, and the Lazy T Milliron. This decline also indicates withdrawals are exceeding recharge and declines may have increased recently because of the reduced streamflows down both Steels Fork and Little Horse Creek as described in Chapter 7.

Water table hydrographs have been prepared for 17 wells and included as Figures 3A-E. These wells were selected because of their length of record or number of data points and considering their location. Figure 3A contains data for 6 wells with the top well being one of the most northern wells owned by Preisser in Section 29, Township 14S, Range 58W. The lower hydrographs are located downgradient over a distance of about 3 miles. The top 3 hydrographs are for irrigation wells located in Section 29. The lower 3 hydrographs are for either observation wells or a livestock well which were initially measured by Brogden in 1985. The top three hydrographs show continually declining water levels ranging from 0.65 to 1.47 feet per year. There are additional irrigation wells upstream of Section 29 which are also responsible for the declines but the greater decline of Travelers #2 is due to its location near several other irrigation wells. The observation well number 5 also has a rate of decline of about 1.5 feet per year. Monthly data are available for the bottom three hydrographs which show seasonal fluctuation of water levels with declines during the pumping season followed by recovery in the winter months. The further south the well the less the decline but decline is occurring.

Figure 3B contains four hydrographs again selected with the most northern well at the top of the sheet and the last hydrograph is the most southern. This line of hydrographs is located about one mile west of those on Figure 3A. The reason for the decline and rate of decline is similar to the discussion for Figure 3A. The observation well #10, lower hydrograph, is about one mile north of the spring and seep area on the east branch of Steels Fork. Seasonal fluctuations are obvious and the limited data suggest that the depression cone caused by irrigation puming moves the three miles downstream over a 4-6 month period. Continuous water level recorder data would verify or refine this conclusion.

Figure 3C contains four hydrographs for irrigation wells located in Section 22, Township 14S, Range 58W owned by Mr. Preisser. The only data available for these wells was the static level when the well was drilled and monthly data collected since October 1988. Three of the hydrographs show significant decline. These wells are all located east of Little Horse Creek and withdraw water from a different bedrock channel than those on Figures 3A and 3B. The amount of recent pumping by these four wells is unknown but there is some evidence to suggest the declines may be due to pumping several years ago and at that time the decline may have even been greater. A decline in water levels at this location would impact ground water outflows to Little Horse Creek.

Figure 3D is a hydrograph for a stock well located about one-fourth mile south of Steels Fork in Section 34, Township 14S, Range 59W. The static water level reported on the 1962 completion report was 81 feet below land surface. The level in that well has now declined to 105 feet and it also shows seasonal fluctuations. It may also reflect recharge from intermittent streamflow in Steels Fork due to rainfall runoff. The 24-foot decline could be caused by the extensive irrigation development located north and west of the well.

Figure 3E is a hydrograph for the Reid #1 well located in Section 1, Township 17S, Range 57W. Measurements prior to October 1988 were made by Mr. John Reid prior to the start of the wells for the irrigation season. The 1950 and 1962 data were taken from the completion reports for the original well and the replacement well constructed in 1962. This well shows annual variations which correlate with the amount of water diverted by the Brooks Ditch. Water levels rise following years of higher diversions and decline when diversions decrease. The aquifer at this location is at the confluence of the Steels Fork and Little Horse Creek bedrock channels and would be influenced by streamflow recharge immediately upstream. Data collected since October 1988 show a seasonal recovery of 3.5 feet.

Conclusions

Ground water usage is extensive throughout the basin and includes significant use for irrigation. Near the concentration of irrigation wells there has been significant declines in water levels; as much as 60 percent of the original saturated thickness is gone. The declines in the Nussbaum-Eolian aquifer have also reduced the outflow from this formation into Steels Fork and Little Horse Creek.

Table 5 contains the computed outflows through cross-section A-A′ for the predevelopment (historic) period and also 1988. For the East Steels Fork/ Little Horse Creek portion of the section the historic flow was 5719 acre-feet per year and in 1988 it was only 3920 acre-feet per year. This represents a 1799 acre-feet per year reduction in outflow from the Nussbaum-Eolian sands into Steels Fork. This equates to approximately 2.5 cubic feet per second continuously throughout the year.

Section D-D′ is a NW-SE cross-section drawn on the east side of the ground water divide between Little Horse Creek and the East Branch of Steels Fork. A comparison of the historic outflow through that section versus the 1988 outflow shows a 3367 acre-feet per year decrease in flow. This corresponds to a continuous flow rate of 4.6 cubic feet per second.

In the lower alluvial-slope wash aquifer, there have been some significant declines in saturated thickness. It is not clear at this time whether ground water rights for this aquifer can obtain their decreed or permitted rates. Declines as evidenced by the Reid #1 hydrograph are continuing.

CHAPTER 7

SURFACE WATER

Streamflow Data

The streamflows of the Horse Creek basin have been measured sporadically providing data with a limited period of record. The earliest data were collected from 1940 to 1947 at a gaging station on Horse Creek near Sugar City. This gage was located in Section 12, T21S, R66W at the bridge on State Highway 96. These streamflow records are available in USGS Water Supply Paper 1311. These data were influenced by irrigation return flows from the Colorado Canal, which diverts water from the Arkansas River. A portion of the Colorado Canal lands below Lake Henry are located in the Horse Creek basin above this gage.

The firm of Bishop, Brogden and Associates installed three Parshall flumes on Steels Fork and the East Branch of Steels Fork on the Smith Ranch in 1985 and readings of the staff gages have been taken about once a month. The locations are shown on Figure 4 and Plate 15 and are identified as station Nos. 12a, 12b, and 12c.

An additional 17 streamflow observation stations in the basin in September, 1988, were established as part of this study. Their locations are also shown on Figure 4 and Plate 15. The data collected at all the locations are tabulated in Table 7. These data were measured using hydrographic equipment and experienced hydrographers. Ice effects were noted on December 29, 1988.

Description of Streamflow

Horse Creek Mainstem

The Horse Creek at the Sugar City gage (station No. 1, Figure 5A) data for the 1940's indicate that Horse Creek had a minimal baseflow in the winter months of 1 to 2 cfs. Since September of 1988, the station has had a maximum flow of 0.22 cfs on September 24, 1988, and has subsequently declined to about 0.03 to 0.04 cfs for the majority of readings.

The summer flows in the 1940's correlate to rainfall amounts in excess of two inches per month as measured at the Rush precipitation station. The monthly values of precipitation for the Rush and Karval stations and the monthly streamflow are shown on Table 6. It is unfortunate that the gaging station was not operated for a longer period so that additional data for analysis of rainfall and runoff correlation would be available.

Flows in Horse Creek upstream of the Sugar City gage are known to be intermittent in several reaches and are shown on USGS 1:24,000 topographic maps. From the lower basin boundary upstream to approximately a mile below the Box Springs Canal the flow is intermittent. From this point upstream to near Forder (Section 8, T16S, R56W), Horse Creek is shown to be perennial. Actually, Horse Creek in this reach has a baseflow that is usually consumed by evapotranspiration from native vegetation, irrigation by the Box Springs Canal and possibly the Forder water rights during the growing season. After the irrigation season and killing frost, the baseflow is re-established. The data from station 2B, Table 7 and Figure 5B, indicates this flow pattern. Additionally, Mr. Kenneth Carter (December 1988 and January 1989 interviews), a long-time resident of the area, indicated that in the 1940's this reach had a baseflow of 3 to 4 cfs in the winter months.

Upstream of Forder, Horse Creek appears to be intermittent without a baseflow in late 1988 and early 1989. This is shown by the data collected at gaging station Nos. 6 and 7 (Figures 5C and 5D). As of February 16, 1989, no flow was measured at either location. However, further upstream where Horse Creek flows under State Highway 94 (gaging station No. 8), the flow increased from 0.04 cfs on September 24, 1988 to over 2 cfs on November 28, 1988 and increased to 5.94 cfs on February 16, 1989 (see Table 7 and Figure 5E). A similar flow pattern was observed for gaging station No. 9 (Figure 5F) about three miles upstream. These flow patterns were influenced by reduction of evapotranspiration by native vegetation after the killing frost and by upstream diversions for irrigation and storage by several senior surface water rights in that reach. This baseflow was derived from discharge of ground water into the stream from the Nussbaum formation at its contact with the Pierre Shale.

Upstream of these senior water rights in Section 31, T12S, R59W, Horse Creek is dry year around except for flood flows.

Little Horse Creek

Little Horse Creek joins Horse Creek in Section 16, T17S, R56W. Upstream from this confluence to gaging station No. 11, Little Horse Creek now flows intermittently, although the USGS topographic maps indicate it to be perennial. Flow data collected in 1988 and 1989 at gaging stations No. 4 (Figure 5G) and No. 15 (Figure 5H) do not show any flow. The next gaging station upstream, No. 11, indicates a flow of 0.40 cfs on September 24, 1988, and flows increased to a maximum of 2.63 cfs on January 6, 1989 (see Table 7 and Figure 5I). At gaging station No. 10, upstream approximately five miles, a flow of 0.40 cfs was measured on September 24, 1988 and flows increased to a maximum of 0.77 cfs on February 16, 1989 (see Table 7 and Figure 5J). In the reach between these gaging stations, the flow is derived mainly from ground water discharging from the Nussbaum formation at its contact with the Pierre Shale as shown by springs on the USGS topographic maps. Approximately one mile upstream of gaging station No. 10 where the east-west county road (Section 22, T24S, R58W) crosses Little Horse Creek, no flow was observed on January 11, 1989. The flow in the reach between this county road and gaging station No. 11 is influenced by evapotranspiration losses and varying spring discharges. There are no known irrigation diversions in this reach, but further field work in 1989 will verify this.

Upstream of the county road (Section 22, T24S, R58W), Little Horse Creek is dry year-round except when flowing after intense rainfall events.

Steels Fork

Steels Fork joins Horse Creek in Section 28, T17S, R56W. In the reach from the confluence to the Brooks Ditch (SE1/4, Section 35, T16S, R57W), Steels Fork is intermittent, flowing only when rainfall events cause excess runoff. (See data for gaging station No. 3, Table 7). At the Brooks Ditch headgate, there is a measuring section and data for gaging station No. 5 (Figure 5k) is collected at this location. No flow was measured at either station No. 3 or No. 5 for the September 1988 to February 16, 1989 period. According to George Reid (interview on January 11, 1989, and deposition), the flow in Steels Fork resumes in the fall after evapotranspiration losses from native vegetation and after upstream diversions and storage cease. The flow in Steels Fork at the Brooks Ditch has been diverted to irrigate hay and native grass including winter irrigation. Records of flow at the Brooks ditch headgate have been maintained by George Reid since 1969. Steels Fork historically began flowing in the late fall, but in recent years it has taken two to three months longer to reach the Brooks Ditch. This year it had not reached the Brooks Ditch by February 16, 1989.

Between the Brooks Ditch headgate and gaging station No. 14 (Figure 5L) (Section 28, T16S, R57W), a reach of approximately six miles exists which overlies alluvial material. When Steels Fork flows over this alluvium, it recharges the unsaturated alluvium and establishes a ground water mound under the creek bed. The amount of streamflow and the depth to ground water influence how long it takes to saturate the alluvium beneath the creek bed. The alluvium beneath the stream for this entire reach must be saturated in order for the baseflow to reach the Brooks Ditch.

The slow advance of flow downstream can be observed by comparing the hydrographs of gaging stations 13 and 14 and from field observations made below gaging station No. 14. At gaging station No. 13 (Section 2, T16S, R57W) approximately seven miles upstream from gaging station No. 14, the flow significantly increased on November 14, 1988 when compared to the previous measurements (Table 7 and Figure 5M). This increase occurred after upstream reservoirs filled and evapotranspiration from native vegetation declined. The flow at gaging station No. 14 (Figure 5L) did not indicate a significant increase until the measurement on November 28, 1988. It appears that it took approximately 24 days for the increased flow to reach the lower station. This delay is attributed to filling several small reservoirs constructed on the Smith Ranch and recharge to the alluvium along approximately one mile of the creek in Section 21, T16S, R57W.

The streamflow at station 14 increased to over 3.5 cfs on December 15, 1988 and further increased to about 5 cfs on February 16, 1989. Even with these flows the stream advance had only moved about two miles downstream to the county road on the east side of Section 34, T16S, R57W, on January 11, 1989. At that location, the streamflow disappeared into the alluvium. Subsequent observations by hydrographers on January 18 and February 16, 1989, indicated that the streamflow was advancing further downstream.

According to Mr. George Reid, once the streamflow reaches the Brooks Ditch headgate, it continues to flow until the next spring except when extremely cold weather causes freeze-up. When upstream diversions and evapotranspiration by native vegetation begin in the spring, this causes Steels Fork to stop flowing except for runoff from intense rainfall events.

Upstream from gaging station 14 for a distance of approximately 15 miles to Section 7, T15S, R58W, Steels Fork derives considerable baseflow from ground water discharge from the Nussbaum formation at the contact with the Pierre shale along the north and east side of the valley. These springs are shown on the USGS topographic maps and can be readily observed in the field. The magnitude of the streamflow obtained from the ground water discharge can be observed from data in Table 7 and Figures 5N, 5O, 5P, and 5M for gaging station Nos. 12A, 12B, 12C, and 13. During the irrigation season, the baseflow in this reach is consumed by irrigation and by evapotranspiration by native vegetation and no flows reach gaging station No. 14 except from intense rainfall events.

The data collected by Bishop, Brogden, and Associates and this office for gaging station Nos. 12A, 12B, and 12C are shown on Figure 5Q. Station 12C shows the most variability since it is below Brett Gray Reservoir. Gaging station Nos. 12A and 12B show a consistent pattern of flow.

Upstream of the west side of Section 6, T16S, R58W, Steels Fork is normally dry except when flowing from intense rainfall events.

Breckenridge Creek and Tributaries

Breckenridge Creek joins Horse Creek in Section 21, T20S, R56W. Breckenridge Creek has three major tributaries: Pond Creek (also known as Dead Horse Creek), Lone Tree Creek, and Cramer Creek. Even though this watershed contains approximately one-third of the drainage area of the Horse Creek basin, it does not appear to have the proportionate baseflow contribution from ground water discharge and the evapotranspiration losses by native vegetation as compared to the remainder of the Horse Creek basin.

Data from gaging stations 2A, 16, and 17 are presented in Table 7. There has been very minimal flow observed at gaging stations 16 and 17 on Pond Creek and Dead Horse Creek, respectively, since September 24, 1988. Breckenridge Creek has shown minimal flow at gaging station 2A with a maximum of 0.027 cfs on January 6, 1989. These stations do not appear to be influenced significantly by reduced evapotranspiration.

There appears to be some subirrigation of native vegetation and hay on Cramer Creek in Sections 20 and 21, T17S, R58W. This is in an area where ground water discharges from the Nussbaum formation at the contact with the Pierre Shale.

Breckenridge Creek except for the seven mile reach upstream of its confluence with Horse Creek can be considered intermittent and the only significant flow is in response to intense rainfall events.

CHAPTER 8

WATER RESOURCE DEVELOPMENT

History of Water Development in the Basin

A map overlay of the basin (Plate 14) has been prepared which shows the location of all water rights from Table 1. The map symbols indicate whether the water right is an alluvial well, a bedrock well, or a surface water right. The outline of the area covered by 7 1/2 minute topographic maps for the study area have been shown and a map number assigned. Each water right on a topographic map area has been assigned a number. These numbers are shown in the first two columns of the water rights listings (Tables 1, 2, and 3) so that a water right can be located on Plate 14. For example, the Cutler Ditch and Reservoir water right is No. 1 on topographic map area B3 on Plate 14. These water rights have also been plotted on overlays of the individual 7 1/2 minute topographic maps for future field work.

Tables 1, 2, and 3 are listings of water rights in the basin by administration number, location, and water right name (alphabetically). These tabulations contain data that has been extracted from decrees and well permits. As stated above, the first two columns contain numbers that allow the water right to be located on Plate 14. The third column indicates what type of structure it is and that code is also explained on the tables. The fourth column contains the use code and the code is explained on the tables. The fifth column contains the water right or well name. The sixth column contains the well permit number if it has been permitted. The seventh column indicates the location of the water right. The eighth column contains the Water Court or civil court case number. The ninth column provides the administration number for each water right which permits a numerical ranking of water rights considering the date of appropriation and date of adjudication. It is based upon the number of days after January 1, 1850 that each event occurred. Thus, the smaller the administration number, the more senior it is. Unadjudicated water rights have an administration number of 99999.99999 to indicate this status. The tenth and eleventh columns indicate the decreed amount and the units whether cfs (c) or acre-feet (A). The twelfth column provides the annual volumetric limit in acre-feet for wells as contained in the decree or permit. The thirteenth column provides information on acres irrigated as allowed in the decree or as shown on the permit. The fourteenth column contains additional information extracted from the decree that may be helpful in understanding the interrelationship of water rights and on water use. Columns fifteen, sixteen, and seventeen contain the adjudication date, the previous adjudication date, and the appropriation date, respectively.

Mainstem Horse Creek

The most senior surface water rights in the study area exist along Horse Creek. The earliest surface water rights within the study area of the Horse Creek basin occur in the extreme upstream reach of Horse Creek in Section 36, T12S, R60W, and Section 31, T12S, R59W. These rights are the Cutler Ditch and Reservoir and the Viaduct No. 2 and Reservoir. As can be seen on Plate 13, which is a straight line diagram of the study area, there are several other senior surface water rights located in the upstream reaches of Horse Creek. The most senior water right in the lower reach of Horse Creek is the Box Springs Canal located in Section 20, T18S, R56W. The Box Springs Canal has a decreed capacity of 440 cfs and was developed during the period from 1899 to 1909. The relative location of the various water rights along Horse Creek within the study area are shown on Plates 13 and 14.

The Box Springs property, which is currently owned by the Carter family, was originally developed by the Burrell Seed Company. The Carter family purchased the lands and water rights from the seed company and gained controlling interest in 1938. The Burrell Seed Company supplemented crop needs with ground water and constructed the first battery of wells in 1914. Eventually over twenty irrigation wells were constructed on the Box Springs property; however, the total pumping capacity of these wells is limited to about 3.0 cfs by decree.

The Hixson Pumping Plants and wells, which were constructed in 1938, were eventually purchased by the Horse Creek Grazing Association and appear to have not been used in recent years for irrigation. Some of these wells were forced to cease pumping in the 1960's as a result of a stipulation between Kenneth Carter and the Hixson Ranch.

Steels Fork

The Steels Fork basin water rights were not adjudicated until CA 416 in 1960. The most senior water rights in this basin are located on the Smith Ranch property and have a 1919 appropriation date. The Smith Ranch water rights are those shown above the Kuester Reservoir water rights as shown on Plates 13 and 14. The next most senior water right on Steeles Fork, the Bouldin Ditch, is located on the Lazy T Milliron Ranch with a 1930 appropriation date.

The Brett Gray Ranch, which is now a part of the Smith Ranch property, was and still is the most heavily cropped area on Steels Fork. The ranch has the benefit of spring flows from the Nussbaum formation. These springs provide significant subirrigation of pasture grasses on the ranch and also support a live stream on a portion of the property. Several reservoirs and ditches were constructed along Steeles Fork to irrigate lands that were not adequately subirrigated. The most downstream water rights on the Smith Ranch property are the Brett Gray Ditches 1 and 2. Due to the irrigation practices on this ranch, the subirrigation of pasture grasses, and a limited water resource, very little if any, streamflow leaves the property during the growing season. Streamflows historically have reached the Bouldin Ditch and Brooks Ditch after the irrigation season and after naturally occurring evapotranspiration declines due to frost.

Little Horse Creek

In the Little Horse Basin the most senior water rights are irrigation wells. In 1937 and 1938, two of the five Kuester wells were constructed in the lower end of the basin, and the remaining three wells were constructed in 1948 and 1950. The first surface water rights were the Reid Ditches 1, 2, and 3 which were developed in 1939. The ditches; however, are not senior water rights in the basin since they were not adjudicated until 1971.

During the period from 1948 to 1958, twenty-eight (28) irrigation wells were constructed in the lower reaches of both Little Horse Creek and Steels Fork where the alluvium is recharged by both streams and is capable of supporting well pumping. The Logan and Kuester wells were constructed at the northern portion of the alluvial aquifer associated with these two tributaries. In the 1960's, four more irrigation wells were constructed in this alluvial aquifer.

Breckenridge Creek

The Breckenridge Creek basin has experienced limited irrigation development. The earliest decreed irrigation water right, the Windmill Lake Supply and Canal, has a 1905 appropriation date. These rights are located on Breckenridge Creek. There are very few irrigation rights within the basin, due to limited water resources. The area is primarily developed as dry land farming and cattle ranching. There are isolated areas on Cramer Creek which have spring flows from the Nusbaum formation that result in subirrigated native hay lands.

Surface Water Development

Surface water development dates back to 1899 in the study area. As can be seen on Figure 6, the irrigation water rights by 1919 had appropriations totalling approximately 700 cfs which far exceeds normal flows in the basin. Some of the larger decreed surface water rights could only fully divert during high flood flows. All of the surface water irrigation rights decreed within the study area are shown on Table 8.

There are 33 irrigation water rights decreed within the study area. Water Commissioner diversion records for these irrigation rights in the area have been reviewed. Many of the diversion records are incomplete and consist of user supplied information reported by the owners to the Water Commissioner for former Water District 17. No attempt was made to determine the overall reliability of the diversion records. The diversion records have been summarized in Table 10. Some records extend back prior to 1940, however, that year was selected as the initial year for this study in order to include a period when minimal well development existed and there were good supplies of surface water.

The first storage rights in the basin were initiated in 1899. Virtually all storage rights that were decreed within the study area were constructed by 1919, and by that time, as shown in Figure 7, approximately 6,500 acre-feet in storage rights had been appropriated. There are 32 decreed storage rights in the study area. Storage records that are available were reviewed and summarized in Table 10 for the 1940 to 1987 period.

Ground Water Development

Well development for irrigation purposes did not begin in earnest until around 1948. This was due to the fact that it wasn't until the late 1940's that electricity reached the area. Earlier wells were powered by windmills and later by large diesel or propane engines. During the drought of the early fifties, the number of wells dramatically increased as shown on Figure 8. Another growth in wells occurred in the 1960 to 1970 period, when well irrigation increased in the Nussbaum Formation and to a lesser degree in the Denver Basin aquifers. Both aquifers provide an irrigation water supply to an area that prior to the advent of large irrigation wells had seen the land used primarily for cattle ranching. The primary aquifer utilized is the Nussbaum formation with at least 52 wells. The Denver Basin aquifers support at least four irrigation wells.

The first irrigation wells constructed in the upstream reaches (Nussbaum formation) of Steels Fork, Little Horse, and Horse Creeks were the two Summer's wells constructed in 1949. In the 1950's, eight more irrigation wells were constructed. In the 1960's, twenty-eight more irrigation wells were drilled in this area with decrees allowing pumping of approximately 14,000 acre-feet each year. This amount of water decreed during the 1960's exceeded the total amount of water decreed to all wells throughout the previous fifty years in the entire study area. From 1970 to 1972, another fourteen wells were constructed in the Nussbaum formation allowing an additional 3,000 acre-feet to be pumped. In the 1970's and 1980's, this area saw the development of numerous sod farms which irrigate with center pivot sprinklers from mid-March to late-November. The construction of these wells has resulted in significant additional lands being irrigated in this portion of the basin that did not exist until the 1960's.

There are 147 ground water rights decreed for irrigation use in the basin, 19 ground water rights decreed for municipal use, 68 ground water rights decreed for stockwater use, and 61 ground water rights decreed for domestic use. Some wells are decreed for multiple uses so the number of wells constructed do not total up to the number of decreed uses. There are also numerous small capacity non-irrigation Denver formation wells permitted in the study area which are a minor source of water. Records of historic pumping for irrigation and municipal use are not available due to a lack of measuring devices. During Phase I of the plan for administration, data will be collected to estimate diversions and uses that have occured in recent years and to obtain water use for 1989.

Summary

When analyzing the development of water rights in the basin, it is very evident that well development is an important source of water to the area. Without the existence of wells to supplement surface water rights, there would not be sufficient water to meet the existing needs of an already over-appropriated and water short basin. The upstream portions of Steels Fork, Little Horse Creek, and Horse Creek would still be used for dryland farming or cattle ranching. At the same time, it must be recognized that well pumping in the upstream portions of these basins has resulted in reduced spring flows which are a mainstay of streamflows and groundwater recharge to the lower alluvial aquifer. There has been a reduction in flow in the lower reaches of Little Horse Creek and Steels Fork and also in Horse Creek in the vicinity of the Box Springs property.

CHAPTER 9

IMPACTS OF WATER RESOURCES DEVELOPMENT

General Description of Impacts

The impacts of water resource development in the Horse Creek basin upon the surface and ground water systems are difficult to quantify at this time due to insufficient data. However, the impacts can be described based upon interviews with long-time residents, data collected in 1988-89, and other information and data.

The initial development of the water resources in the basin as described in Chapter 8 was by ditches with some wells as a supplemental supply to the Box Springs Canal. This development occurred in the 1899 to 1919 period and was sufficient to cause the basin to be over-appropriated in that the amount of the decreed water rights exceeded the streamflow except during flood events. This initial development can be seen on Figure 6 which is a cumulative graph of the decreed direct flow diversions versus the year of appropriation. The acres of land to be irrigated by these water rights as indicated by the decrees totals 17,125 acres. This information is shown in Table 1 under the "Acre Irrig" column. It should be realized that not all of this land is irrigated. Additional field work in 1989 will map irrigated acres in the basin. As a result of this development, the basin outflow declined as consumptive use of water increased; however, this was acceptable since the development was done within the priority doctrine. Kenneth Carter (January, 1989) indicated that in the 1940's the baseflow would approach 3 to 4 cfs at the Box Springs Canal diversion in the fall after naturally occurring evapotranspiration declined. He also indicated that this baseflow was diverted for winter irrigation by his family when they acquired control of the Box Springs Ditch in the 1930's. Thus, Horse Creek contributed very little water to the Arkansas River except during times of floods.

The second period of development appears to be during the 1928 to 1956 time frame as additional lands were brought under irrigation through wells although some ditches were also constructed. This additional growth can be seen in the tabulation of water rights (Table 1) with administrative Nos. from 28854.0 to 38929.0. The number of additional irrigated acres associated with these rights totals 7,058 acres. Data are not available on their actual water use, but it is estimated that the consumptive use could be two acre-feet per acre or 14,116 acre-feet per year.

This increased irrigation was located in two areas. The first being from wells constructed in the Nussbaum formation in the upper portion of the basin and the second in the alluvial sands and gravel in the lower portion of the basin. The impact of irrigation from the Nussbaum formation by these wells was probably small since only eight wells were constructed that were decreed for 1,265 acres.

The impact of the increased irrigation by ground water pumped from the alluvial sands and gravels in the lower portion of the basin probably caused a decline in the baseflow of Horse Creek above the Box Springs Ditch. However, this baseflow only occurred during the period of the year when the natural evapotranspiration losses from vegetation were minimal or in other words outside of the normal irrigation season. Kenneth Carter (January, 1989) indicated after the drought of the 1950's that the baseflow of Horse Creek never returned to the 1940's levels.

A third period of development appears to be from the 1960 to 1972 period when wells were constructed to irrigate additional lands primarily located where the Nussbaum formation had sufficient saturated thickness to support irrigation by wells. This additional development can be seen in the tabulation (Table 1) with administrative Nos. from 40288.0 to 44925.4. The decreed and permitted acres irrigated from Table 1 of 7,055 acres could cause a consumptive use of 14,110 acre-feet per year if crop consumptive use is 2.0 acre-feet per year. In addition to the construction of new wells during this period, the type of crops being irrigated and the manner of irrigation appears to have changed on some farms. Sprinkler irrigation with center pivot systems has grown considerably since 1975. As a result, more land can be irrigated with the same well. Also, some farms in the Rush area have changed from traditional row crops and small grains to growing lawn turf grass which has a higher consumptive use.

The impact of the additional irrigation from the wells constructed in this post-1960 period which withdrew ground water from the Nussbaum formation caused a decline in discharge from that formation to the springs at the outcrop. The amount of decline in discharge from this development is difficult to estimate due to pumping from ground water storage and the extensive evapotranspiration from subirrigated lands in the vicinity of the springs. An estimate of this decline is provided later in this chapter.

In addition to the development described above that took place legally, there appears to have been other types of water resource development or activities that are either illegal or improper. These activities include construction of erosion control dams on tributaries of Little Horse and Horse Creeks without outlets to pass inflow, expanded irrigation of lands in excess of those decreed or permitted, irrigation of lands by undecreed diversions, and reservoirs storing out-of-priority. These activities can impact streamflow by storing water out-of-priority or by depleting streamflow through additional consumptive uses that are undecreed.

Estimated Impacts Based Upon Present Knowledge of the Basin

The overall impacts of the above described development can be estimated by analyzing the data collected recently as part of this study.

The water levels in both aquifers are declining as shown on the hydrographs, Figure 3, and the map, Plate 5. This decline in ground water levels is caused by pumping exceeding the recharge in each aquifer. This decline has also been reported in interviews with George Reid and Kenneth

Carter concerning water levels in wells with which each person is familiar. The areas with the most significant declines are those areas with intensive irrigation using center pivot systems.

The discharge of the Nussbaum formation at springs along the contact with the Pierre Shale has declined based upon cross-sectional analyses of ground water flow at the time of initial development versus 1988-89 conditions (Table 5). The decline in outflow is estimated to be 1,799 acre-feet per year or approximately 2.5 cfs in the Steels Fork basin. This estimated decline supports statements made by George Reid and Robert Smith in depositions that the springs on Steels Fork are flowing about one-half of their historical amounts. The amount of the decline in ground water discharge to Little Horse Creek basin is estimated to be 3,367 acre-feet per year or 4.6 cfs (Table 5).

The streamflows of the basin are declining according to interviews with George Reid and Kenneth Carter. George Reid has collected data since 1972 on the date water first reaches the Brooks Ditch in the fall or winter. This data indicates that it has taken longer in recent years for water to reach the Brooks Ditch and that the Brooks Ditch diverts less water. This decline is attributed to reduction in ground water discharge from the Nussbaum formation. Kenneth Carter has indicated that the runoff from more intense rainfall events is not reaching the Box Springs Ditch as it did historically and he believes that this is caused by the increase in erosion control dams upstream of the Box Springs headgate. He also has indicated that the baseflow of Horse Creek has declined from those observed in the 1940's.

Based upon the declining water levels in both aquifers and declining streamflow and spring discharge, it is apparent that water use in the basin has exceeded the basin's long-term safe yield. The amount of use in excess of the basin safe yield cannot be determined at this time since the use of water in the basin is not fully known nor can the basin's safe yield be estimated without further study.

Even though ground water levels, streamflow, and spring discharges have declined, injury to specific water users has not been clearly established at this time. Water users in the lower basin have been able to utilize wells to supplement the surface water supply. However, with continued decline of the ground water levels, it is likely these wells will not be able to provide the supplemental water that they have in the past. George Reid stated that he had to replace one pump with a smaller pump to prevent surging and he now has to operate his wells full-time to provide the same volume of water he obtained in the past while pumping a lesser amount of time. If the water levels continue to decline, injury to water users in the lower basin will occur.

While spring flows to Steels Fork have declined, it is not apparent at this time that the Smith Ranch has been injured. Due to the nature of irrigation by the springs on the Ranch, it appears that the acres of native hay under irrigation or sub-irrigation are comparable to historic acres.

The majority of ditches on the Smith Ranch with the exception of the Brett Gray Ditch No. 1 do not show recent use or maintenance. If the spring discharges continue to decline, it is possible that the Brett Gray Ditch No. 1 will be injured. If the Smith Ranch can show that hay production is consistently down in recent years, then it may be possible to show injury.

Water users in the upper basin relying on ground water from the Nussbaum formation are seeing significant declines in water levels that are causing some wells to produce less water. Well users report decreases from 800 gallons per minute to as little as 200 gallons per minute. Mr. Charles Hunt (interview, January, 1989) indicated that his well in Section 11, T14S, R59W, produced about 150 gpm in 1988 as compared to the original 760 gpm. In those areas with the largest decline in water levels (Plate 5), the well production may be only a fraction of the original production. Wells constructed in the 1940's and 1950's have lower static water levels and this is responsible for their reduced well production. All the wells pumping from the Nussbaum buried channel which extends through Sections 29 and 30, Township 14 South, Range 58 West, have contributed to the decline in water table and the resultant reduction in spring outflow to both Steels Fork and Little Horse Creek.

CHAPTER 10

CONCLUSIONS

The Horse Creek basin as defined by this study is over-developed and over-appropriated. Consumptive use of water is exceeding the safe yield of the basin as shown by declining ground water levels in the two aquifers in the basin, by declining spring discharges at the Nussbaum formation contact with the Pierre Shale, and by declining surface flows.

A portion of this consumptive use is by illegal and improper diversions and storage of water. The amount of illegal or improper usage must be identified through additional field work and orders issued to curtail that use. Orders have been issued to the Smith Ranch to install proper outlet devices on 26 erosion control dams on the Ranch or to remove the dams.

Well development in the Nussbaum formation in the upper portion of the basin in the post-1960 period has significantly increased the potential consumptive use of ground water in that area. It is estimated that the ground water outflow through springs from the Nussbaum formation has declined by at least 1,790 acre-feet per year in the Steels Fork basin and 3,370 acre-feet per year in the Little Horse Creek basin. This well development has also resulted in pumping exceeding recharge and lowering of water table elevations in areas of high pumping. This has caused well production to decline.

Additional data must be obtained on water use in the basin and on the basin's average safe yield in order to determine if curtailment of use by junior water rights, which are primarily wells constructed in the post-1960 period, is required. During 1989, measurement of the observation well network and streamflow gages will continue and efforts will be undertaken to accurately estimate decreed or permitted water usage. Water users will be requested to install flow measuring devices or otherwise document their water use.

CHAPTER 11

HORSE CREEK BASIN [1/] WATER RIGHTS ADMINISTRATION PLAN

Phase 1 - 1989

In developing the administration plan as ordered by the Water Court for Division 2, extensive analysis of water rights and water use, aerial photo interpretation, aerial reconnaissance, and field investigations revealed that there appears to be a number of illegal and improper uses of water within Horse Creek Basin. Those illegal and improper uses of water are:

1. Acres irrigated exceeding that allowed by decree or permit
2. Undecreed uses
3. Irrigation from undecreed wells with expired permits
4. Dams constructed without outlet devices
5. Reservoirs and ponds storing water out-of-priority
6. Unadministerable diversion structures
7. Diversions being made without adequate measuring devices

Based upon the above, the first phase of the administrative plan will be to conduct field investigations of these apparent illegal and improper uses and issue appropriate orders to correct these illegal and improper uses. The amount of water consumptively used by these illegal and improper uses will then be compared with estimates of water use collected in 1989 with measuring devices installed by water users. The water usage for 1989 that is in compliance with well permits and decrees will be compared to estimates of average basin yield. In order to effectively correct these illegal and improper uses, the State and Division Engineers request that this court allow expedited proceedings to enforce such orders to ensure compliance when necessary.

Phase II - 1990

An administrative plan may be imposed upon well owners to curtail pumping to maximize the beneficial use of both underground water tributary to the surface streams and surface water rights in the basin. Wells that are used to supplement senior ditch diversions will be allowed to divert under the ditch priority and amount.

Phase III - 1991 and beyond

The State Engineer will monitor water use, ground water levels, and streamflows in the Horse Creek basin to determine if the curtailment in uses is achieving the desired effect. The State and Division Engineers will report to the Water Court periodically during the pendancy of this case.

1/ For the purposes of this plan, the Horse Creek Basin is defined as the area within the Horse Creek drainage upstream of the south side of Sections 28 and 29, T20S, R56W, excluding Black Draw.

LIST OF SELECTED REFERENCES

Beck, R.W., and Associates, 1967, Ground water resources study pertaining to portions of Prowers, Baca, and Las Animas Counties, Colorado: Report prepared for the Colorado Ground Water Comission, Denver, p. 27

Brogden, Robert E. 1973, Lincoln County Groundwater Protest: Leonard Rice Consulting Water Engineers, special report

Chow, Ven Te (Ed.), 1964, Handbook of Applied Hydrology: McGraw Hill Book Co., NY

Colorado Climate Center, 1984, Colorado average annual precipitation, 1951-1980 (map): Department of Atmospheric Sciences, Colorado State University, Fort Collins

Colorado Division of Water Resources, Water-Well Completion Reports

Daubenmire, R.F. 1959, Plants and Environment, 2nd ed: John Wiley & Sons, Inc., NY

Doesken, Nolan J., and Others 1984, Analysis of Colorado Average Annual Precipitation for the 1951-1980 Period: Department of Atmospheric Science, Colorado State University, Ft. Collins, Colo. Climatology report No. 84-4

Duke, H.R., and Longenbaugh, R.A., 1966, Evaluation of water resources in Kiowa and Bijou Creek Basins, Colorado: Civil Engineering Dept., Colorado State University, Fort Collins, p. 36

Erker, H.W., and Romero, J.C., 1967, Ground Water Resources of the Upper Black Squirrel Creek Basin, El Paso County, Colorado: Colorado Division of Water Resources

Hydrokinetics Inc., (1987), Draft report on the Travelers well field: Hydrokinetics Inc., Golden, Colorado

Larsen, Lynn S., Larsen, Roy L., and Others 1966, 1968, 1981, Soil Survey Series: U.S. Dept. Agriculture, Soil Conservation Service

Linsley, Kay K., Jr., and others, 1958, Hydrology for Engineers: McGraw-Hill Book Co., Inc., NY

McLaughlin, Thad G., 1946, Geology and ground-water resources of parts of Lincoln, Elbert, and El Paso Counties, Colorado: Colorado Water Conservation Board, Ground Water Series--Bulletin 1

McGovern, H.E., and Jenkins, E.D., (1966), Ground water in Black Squirrel Creek Valley, El Paso Co., Colo: U.S. Geol. Survey Hydrologic Investigations Atlas, HA 236

Meinzer, Oscar E., (Ed.), 1942, Hydrology: Dover Publications, NY

National Oceanic and Atmospheric Administration, Climataological data for Colorado

Patton, Horace B., 1924, Underground water possibilities for stock and domestic purposes in the La Junta area, Colorado: Colo. Geol. Survey Bull, 27, part I

Resource Consultants Inc., (1978), Geohydrologic investigations, Lazy T Milliron Ranch, Lincoln County, Colorado: Resource Consultants, Inc., Ft. Collins, Colo.

Robson, S.G.,.1983, Hydraulic characteristics of the principal bedrock aquifers in the Denver Basin, Colorado: U.S. Geol. Survey Hydrologic Investigations Atlas, HA-659

Robson, S.G., and Romero, John C., 1981, Geologic structure, hydrology, and water quality of the Dawson aquifer in the Denver Basin, Colorado: U.S. Geol. Survey Hydrologic Investigations Atlas, HA-643

______________ 1981, Geologic structure, hydrology, and water quality of the Denver aquifer in the Denver Basin, Colorado: U.S. Geol. Survey Hydrologic Invest. Atlas, HA-646

______________ 1981, Geologic structure, hydrology and water quality of the Arapahoe aquifer in the Denver Basin, Colorado: U.S. Geol. Survey Hydrologic Investigations Atlas, HA-647

Robson, S.G., Wancinski, Andrew, Zawistowski, and Romero, John C. (Colorado Division of Water Resources), 1981, Geologic structure, hydrology, and water quality of the Laramie-Fox Hills aquifer in the Denver Basin, Colorado: U.S. Geol. Survey Hydrologic Invest. Atlas, HA-650

Romero, John C., 1976, Ground water resources of the bedrock aquifers of the bedrock aquifers of the Denver Basin, Colorado: Colorado Division of Water Resources, special report

Romero, John C., 1988, Field notes of Horse Creek Basin studies conducted in 1968: Colorado Division of Water Resources, Denver, Colo.

Scott, Glenn R., and others, 1978, geologic map of the Pueblo 1° x 2° Quadrangle, south central Colorado, U.S. Geol. Survey Miscl. Invest. Map I-1022

Sharps, Joseph A., (1976), Geologic map of the Larmar Quadrangle, Colorado and Kansas: U.S. Geol. Survey Miscellaneous Investigations Series I-944

Schoeller, H.S., 1959, Arid zone hydrogeology: UNESCO, Place de Fontenoy, Paris -7^{e}, France

Toepelman, W.C., 1924, Underground resources of parts of Crowley and Otero Counties: Colo. Geol. Survey Bull. 27, part II

U.S. Department of Commerce, 1956, Annual, summer, and winter precipitation maps of Colorado (1931-1960): Weather Bureau maps

Van Slyke, G., and others, 1988, geologic structure sandstone/siltstone isolith, and location of nontributary ground water for the Dawson aquifer, Denver Basin, Colorado: Colorado Division of Water Resources, Denver Basin Atlas No. 1, Map DBA-1

__________ 1988, Geologic structure, sandstone/siltstone isolith, and location of nontributary ground water for the Denver aquifer, Denver Basin, Colorado: Colorado Division of Water Resources, Denver Basin Atlas No. 2., Map DBA-2

__________ 1988, Geologic structure, sandstone/siltstone isolith, and location of nontributary ground water for the Arapahoe aquifer, Denver Basin, Colorado: Colorado Division of Water Resources, Denver Basin Atlas No. 3, Map DBA-3

__________ 1988, Geologic structure, sandstone/siltstone isolith, and location of nontributary ground water for the Laramie-Fox Hills aquifer, Denver Basin, Colorado: Colorado Division of Water Resources, Denver Basin Atlas No. 4, Map DBA-4

Wilson, Woodrow W., (1965), Pumping tests in Colorado: Colorado Water Conservation Board, Ground Water Circular II, Denver, Colo.

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