FLORIDA MESA DITCH LOSS STUDY

October 2010

Prepared for:

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Durango, CO

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EXECUTIVE SUMMARY

The Florida Mesa is located in La Plata County, Colorado (See Figure 1). Irrigation land on the Florida Mesa is served by the Florida Canal, Florida Canal Enlargement, Florida Farmers Ditch and Florida Cooperative Canals, herein referred to as the Florida Mesa Canal Companies. The conveyance system of the Florida Mesa Canal Companies experiences both seepage and administrative waste. A 1988 USBR Florida Rehabilitation and Betterment Study to conserve water calculated this waste to be 8,400 acre-feet (AF) per year. Florida Water Conservancy District (FWCD) water monitoring program records indicate that over the last seven years, system losses have averaged 24 percent, or 11,600 AF per year. To better conserve water, the reaches of heavy seepage and ditch losses need to be repaired, lined, piped, or otherwise treated.

Funding was received from the Colorado Water Conservation Board (CWCB) for a range of objectives, including the ditch loss study, purchase and installation of telemetry and automated headgates, and a hydropower feasibility study. The objectives of this report are to 1) determine locations of losses below the main inlet canal structures, and 2) identify and prioritize high seepage areas for future lining and piping projects. The Florida Mesa Canal Companies will use the ditch loss study to further prioritize lining projects previously identified in the FWCD Water Conservation and Management Plan and the USBR Florida Rehabilitation and Betterment Study.

The ditch riders identified the upstream sections of the main canals as the reaches where the most losses might occur (See Figure 2). For the Florida Canal, the greatest losses were identified in the reach from the headgate on the Florida River through the serpentine canyon sections to the Confluence. For the Florida Farmers Ditch, the greatest losses were identified in reach from the headgate on the Florida River to the Confluence. For the Florida Farmers Ditch West, the greatest losses were identified in the reach just south of US Highway 160.

The scope of this study includes 1) the Florida Canal from the headgate at the Florida River to the Confluence, 2) the Florida Farmers Ditch from the headgate at the Florida River to the Confluence, 3) the Florida Canal South from the Confluence to Pastorius Reservoir, and 4) the Florida Farmers Ditch West from the Confluence to Pastorius Reservoir.

Meetings with the ditch riders for the Florida Canal Companies were extremely helpful, and their assistance with the fieldwork was essential for a successful study. Meetings also were held with the FWCD to formulate the plans for the overall study and to help write the proposal.

According to the estimated annual losses during high flow conditions in AF per year (i.e., sheer volume of water), the largest loss occurs in the Florida Farmers Ditch from the headgate to the Payne Canyon siphon, which is labeled Reach G on Figure 2. Large annual losses also occur in Reach H (Florida Farmers Ditch), the next reach downstream from Payne Canyon. These estimated annual volumes are presented as an indication of the magnitude loss that occurs under relatively high flow conditions.

Large annual losses were likewise calculated in the Florida Canal from the headgate to County Road (CR) 234 and from the Macho property to Horse Gulch in Reach C (See Figure 2).

Table ES-1

Annual Losses Summary

Reach I.D.	Canal	Location	Annual Losses in Acre-Feet/Year [1]	Length (miles)	Acre-Feet/Mile
G	Florida Farmers Ditch	Headgate to Payne Canyon	3,932	1.5	2,620
H	Florida Farmers Ditch	Payne Canyon downstream	2,607	1.2	2,170
L	Florida Farmers West	Confluence to Highway 160	1,602	2.5	640
K	Florida Canal South	CR 172 to Pastorius	1,341	2.7	500
C	Florida Canal	Macho property to Horse Gulch	1,211	1.0	1,200
M	Florida Farmers West	Highway 160 to below Grandview	767	1.6	480
A	Florida Canal	Headgate to CR 234	536	0.5	1,070

[1] Based on high flow conditions and 150-day irrigation season.

Follow-up visual reconnaissance observations and meetings with Canal Company representatives focused on the highest priority candidate lining sections as the Florida Farmers Ditch from the headgate to approximately CR236. This is due to large losses based on measurements, geology, soils, vegetation observations and good construction access.

1.0 INTRODUCTION — BACKGROUND

The Florida Mesa, located approximately ten miles southeast of Durango, Colorado, has been a productive agricultural region since the construction of the Florida Canal system in the 1880s (See Figure 1). The Florida Farmers Ditch Company was formed in 1889, and the Florida Canal Company in 1893 in order to provide adjudicated irrigation water to agricultural water users on the Florida Mesa. The Florida Enlargement Canal Company and the Florida Co-Operative Ditch Company were formed in 1908 and 1910, respectively, which expanded delivery of agricultural water to farmers on the Florida Mesa (all referred to collectively as the Florida Mesa Canal Companies). The Florida Mesa Canal Companies provide water to shareholders serving 18,700 acres of irrigated agriculture. The Florida Farmers Ditch is decreed for 45 cubic feet per second (cfs), Florida Canal for 40 cfs, Florida Canal Enlargement for 40 cfs, and the Florida Co-Operative for 30 cfs, for a total decreed rate of flow of 155 cfs for irrigation purposes. In addition, the Florida Mesa Canal Companies provide water to Pastorius Reservoir, which is a Colorado State Wildlife Area. On average, the Florida Mesa Canal Companies deliver 24,125 AF of water per year. The Florida Mesa Canal Companies operate approximately 86.5 miles of canals, ditches, and laterals.

In the 1930s, the U.S. Bureau of Reclamation (USBR) conducted feasibility studies for construction of the Florida Project, and Lemon Reservoir was constructed in 1963, which provides supplemental and sole supply irrigation water for 19,450 acres of agricultural land. Lemon Dam is the principal feature of the Florida Project, which is a participating project of the Colorado River Storage Project. The dam is located in southwestern Colorado on the Florida River, approximately fourteen miles northeast of Durango in La Plata County. Lemon Reservoir is approximately one half mile wide and three miles long with a surface area of 622 acres, and the total capacity of the reservoir is 40,146 AF. In addition to the construction of Lemon Dam, the USBR work included rebuilding the Florida Farmers Diversion Dam, enlarging 3.9 miles of the Florida Farmers Ditch, and building a new lateral system to serve approximately 3,360 acres of land in the southeast portion of the Florida Mesa. Including the Southern Ute Indian Tribe (SUIT), there are 1,003 project users.

Water is released from the reservoir for project users located on the Florida Mesa and is conveyed thirteen miles through the Florida River main stem to the headgates of the Florida Canal and Florida Farmers Ditch (See Figure 2). Water is subsequently diverted into a complex series of ditches and laterals to distribute the water to irrigated lands. The two main ditches join for a short section referred to in this report as the Confluence (See Figure 2). Water measurement devices, located at every headgate and diversion, are an important aspect of the irrigation water delivery system.

The conveyance system of the Florida Mesa Canal Companies experiences both seepage and administrative waste. A 1988 USBR Florida Rehabilitation and Betterment Study to conserve water calculated this waste to be 8,400 AF per year. Florida Water Conservancy District (FWCD) water monitoring program records indicate that over the last seven years, system losses have averaged 24 percent, or 11,600 AF per year. In 2006, the FWCD and the Florida Mesa Canal Companies undertook a Water Conservation and Management Plan. During the planning process, the increase in efficiency of the Canal Conveyance System was identified as a goal of both the FWCD and the Florida Mesa Canal Companies.

In 2009, a grant was received from the Colorado Water Conservation Board (CWCB), Southwest Basin Roundtables, to conduct a ditch loss study. The result of the ditch loss study, described in this report, quantifies the seepage losses occurring in major reaches of the canal system. Flow recorders, telemetry, and automated gates were also funded in part by the grant from the CWCB. Using these tools, more efficient recording and operation of the canal system will result in less administrative waste, where irrigation tailwater may be wasted into the river rather than diverted down the canal to areas where it is needed.

To better conserve water, the reaches of heavy seepage and ditch losses need to be repaired, lined, piped, or otherwise treated. As water is conserved and used more efficiently, less water would need to be released from Lemon Reservoir; therefore, the irrigation season would last longer, more crops could be grown, fewer irrigators would have their water curtailed, and the economy would be stimulated through a more efficient and successful crop season.

1.1 Objectives and Scope

Funding was received from the CWCB for a range of objectives, including the ditch loss study, purchase and installation of telemetry and automated headgates, and a hydropower feasibility study. The objectives of this report are to; 1) determine locations of losses below the main inlet canal structures, and 2) identify and prioritize high seepage areas for future lining and piping projects. The Florida Mesa Canal Companies will use the ditch loss study to further prioritize lining projects previously identified in the FWCD Water Conservation and Management Plan and the USBR Florida Rehabilitation and Betterment Study.

The ditch riders identified the upstream sections of the main canals as the reaches where the most losses might occur (See Figure 2). For the Florida Canal, the greatest losses were thought to be in reaches from the headgate on the Florida River through the serpentine canyon sections to the Confluence. For the Florida Farmers Ditch, the greatest losses were thought to be in reaches from the headgate on the Florida River to the Confluence. For the Florida Farmers Ditch West, the greatest losses were thought to be in the reach just south of US Highway 160.

The scope of this study includes; 1) the Florida Canal from the headgate at the Florida River to the Confluence, 2) the Florida Farmers Ditch from the headgate at the Florida River to the Confluence, 3) the Florida Canal South from the Confluence to Pastorius Reservoir, and 4) the Florida Farmers Ditch West from the Confluence to Pastorius Reservoir. Discharge measurements to quantify ditch losses were completed in July 2009. In addition, soils and geology was reviewed, and a site visit to evaluate the subject canals during dewatering conditions was performed in April of 2010.

1.2 Report Organization

This report is organized to first present a description of the canals, associated soils, and underlying geology. The figures presenting soils and geology also include measured losses, by reach, approximately annualized in AF per year on a gross water loss basis. These annual losses allow an understanding of the relative magnitude of loss. The figures and corresponding reaches where measurements were obtained are labeled A through N in Figure 2 to aid the reader and correlate text, figures and tables. Geology observations by the USBR are cited. Consultations with Canal Company representatives are also recapped.

The next section of the report discusses historical flows, and then the detailed canal discharge measurements and ditch loss calculations are presented. This section begins with a discussion of measurement methods. Each canal reach that was analyzed is then described and calculated losses are presented.

Finally, calculated losses are presented in a section of prioritized sections illustrating the largest magnitude losses and measurement device recommendations are provided.

2.0 GENERAL LAYOUT OF DITCHES AND CANAL SYSTEMS

Irrigation water is supplied to the Florida Mesa Canal Companies from two headgates on the Florida River—the Florida Farmers Ditch and the Florida Canal (See Figure 1). The Florida Canal serpentines along steep hillslopes and canyons above the west side of the Florida River valley in order to maintain elevation as it traverses onto the mesa. The Florida Farmers Ditch, having been reconstructed by the USBR during the 1960s, takes a more linear path from the Florida River to the mesa. Both canals are earth lined for their entire lengths, except for short piped sections, drop and check structures, and siphons where the Florida Farmers Ditch is routed under two roads.

The Florida Canal and Florida Farmers Ditch provide water to several small diversions before the canals gain the mesa; however, the majority of the diversions occur on the mesa itself. After gaining the mesa, part of the Florida Canal is diverted into the Florida West Canal, which flows west to the Grandview area, and supplies the Three Springs development with irrigation water (owned by the SUIT). Because of the complex adjudication of the two canal systems, some laterals from the Florida Canal cross over or under the Florida Farmers Ditch to adjudicated lands. The Florida Farmers Ditch and the Florida Canal join into one canal near CR 240 and

228. Informally called the Confluence (See Figure 1), water from the two canals converge for a short segment before it is split again and continue southward as the Florida Canal South, and the Florida Farmers Ditch West. Both the Florida Canal South and Florida Farmers Ditch West terminate at Pastorius Reservoir (See Figure 2).

2.1 Soils

Soils underlying canals and ditches of the study area differ depending on whether the canal is located in the Florida River valley below the headgate or on the Florida Mesa (See Figure 3). As shown on Figure 3, soils were mapped along the canals as depicted in the Soil Conservation Service Soil Survey of La Plata County Area, Colorado. The mapping includes a color covered soils map number, soil type, and permeability range in inches per hour. *Permeability* refers to the ability of a soil to transmit water or air. The estimates indicate the rate of downward movement of water when the soil is saturated. The permeabilities are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Permeability is expressed as the number of inches per hour that water moves downward through the saturated soil. Terms describing permeability are:

Very slow	Less than 0.06 inches/hour
Slow	0.06 to 0.2 inches/hour
Moderately slow	0.2 to 0.6 inches/hour
Moderate	0.6 inch to 2.0 inches/hour
Moderately rapid	2.0 to 6.0 inches/hour
Rapid	6.0 to 20 inches/hour
Very rapid	More than 20 inches/hour

The Florida Canal System, from the headgate to Pastorius Reservoir, is underlain by thirteen different soil units, which are discussed below. Additional information from the Soil Conservation Service Soil Survey of La Plata County Area, Colorado regarding these soils, can be found in Appendix F.

Hesperus Loam, 3-12 percent slopes. Permeability of the Hesperus Loam is moderate and ranges from 0.6 to 2 inches per hour. Significant ditch loss can be expected in areas where the canals cross over the Hesperus loam for a long distance. This was evident in the ditch loss measurements of the Florida Farmers Ditch, where the most significant loss (3,932 AF/yr) occurred in Reach G, which crosses over this soil type (See Figure 3).

Rock outcrop. Permeability rates for rock outcrops vary depending on the composition and structure of the outcrop. Significant ditch loss may occur in rock outcrop that are highly fractured or poorly cemented.

Tefton Loam. In general, the permeability of the Tefton loam is moderate or moderately slow. It ranges from 0.6 to 20 inches per hour, depending on the depth of the soil. Due to the presence of a high water table associated with this soil coupled with a moderately slow permeability rate at the surface, significant ditch loss is not anticipated in this soil horizon. The Tefton loam is encountered in Reach B, of the Florida Canal, on Figure 3, and this reach exhibited the lowest annual volume of loss (149 AF/yr) that was identified in the study.

Ustic Torrierthents-Ustollic Haplargids complex. Permeability of the Ustic Torriorthents - Ustollic Haplargids complex varies depending on the texture of the parent material, but ranges from 0.6 to 2 inches per hour. Significant ditch losses have been measured in ditch reaches that cross over the Ustic Torrierthents-Ustollic Haplargids complex. Payne Canyon contains soils of the Ustic Torrierthents-Ustollic Haplargids complex, and this is an area that has been identified by the ditch riders of the Florida Mesa Canal Companies as an area of known ditch loss in the Florida Canal. This soil is mostly encountered in reaches E and G on Figure 3.

Archuleta-Sanchez Complex, 12 to 65 percent slopes. Permeability of the Archuleta soil is moderate. Permeability of this Sanchez soil is moderately slow. Permeability if the Archuleta-Sanchez complex ranges from 0.6 to 2 inches per hour. The Florida Canal passes over the Archuleta-Sanchez complex for a relatively short distance on Reach B shown on Figure 3. Moderate ditch loss could result from the reach that crosses over the Archuleta-Sanchez complex based on its range of permeability.

Vosburg Fine Sandy Loam. Permeability of the Vosburg soil is moderate and ranges from 0.6 to 6 inches per hour. This soil is encountered on the Florida Canal where the canal crosses Horse

Gulch on Reach D (See Figure 3). Significant losses resulting from this soil could be expected due to its high permeability rate.

Shawa Varient loam, 5 to 20 percent slopes. Permeability of the Shawa Variant soil is moderate and ranges from 0.6 to 2 inches per hour. The Florida Canal encounters this soil as it serpentines between Horse Gulch and Payne Canyon on Reach D of Figure 3. Moderate losses could be expected from this soil type due to its moderate permeability rate.

Falfa clay loam, 1 to 3 percent slopes and Falfa clay loam, 3 to 8 percent slopes. Permeability of the Falfa soil is slow and ranges from 0.1 to 0.6 inches per hour. Significant ditch losses are not anticipated in sections of ditch that cross over the Falfa clay loam. Ditch loss measurements of ditch reaches that cross the Falfa clay loam were among the lowest losses in the study. These reaches include F, I, J, and N (See Figure 3).

Simpatico loam. Permeability of the Simpatico soil is moderately slow and ranges from 0.2 to 2 inches per hour. Moderate losses could be expected in reaches that cross the Simpatico loam. Reach L crosses through multiple soils, but the Simpatico soil is likely the soil causing losses within this reach, because when compared to the adjacent soils, the Simpatico loam is generally more permeable than the adjacent soils (See Figure 3).

Arboles Clay, 3 to 12 percent slopes. Permeability of the Arboles soil is slow and ranges from 0.1 to 0.2 inches per hour. Because the permeability of the Arboles Clay is so slow, significant ditch loss is not anticipated from this soil. This soil is encountered by the Florida Farmers Ditch West on the top of Florida Mesa, on Reach L shown on Figure 3.

Pescar fine sandy loam. Permeability of the Pescar soil is moderately rapid and ranges from 2 to 20 inches per hour, depending on depth. Significant ditch losses could be expected in reaches that cross over this soil type. A short segment of the Florida Canal crosses this soil type on Reach K (See Figure 3).

Zyme clay loam, 3 to 25 percent slopes. Permeability of the Zyme soil is slow and ranges from 0.1 to 0.6 inches per hour. The Zyme clay loam is encountered by the Florida Farmers Ditch

West on top of the Florida Mesa in Reach L shown on Figure 3. Significant ditch losses are not expected from ditch segments that cross through this soil type.

In general, the soils below the mesa tend to have a more rapid permeability rate, while the soils on the mesa top tend to have a slower permeability. It should be noted that deposition of sediments carried in the canals may not necessarily correlate to the surrounding soils, outside of the ditch. These canal-deposited sediments may act to "self-line" the ditch, and may not exhibit the same characteristics of the surrounding native soils.

2.2 Geology

Geologic units of the study area are comprised of consolidated rocks of Cretaceous and Tertiary age and unconsolidated sediments of Quaternary age (See Figure 4). Cretaceous rocks crop out in a series of northeast-southwest-trending hogback ridges and intervening valleys along the northern margin of the study area and dip southward into the northern rim of the San Juan Basin (Robson and Wright 1995). Sandstones tend to be more resistant to weathering than shales; as a result, sandstone units commonly form ridges and steep hillslopes with shale units forming the intervening valleys. Younger (Tertiary) rocks crop out or subcrop under unconsolidated sediments in most of the central and southern part of the study area and are relatively flat lying.

The Animas Formation (map unit TKa, Figure 4) is the primary bedrock unit underlying most of the study area. The surface of the top of the Animas Formation slopes to the south and southwest and ranges in elevation from about 7,150 to 6,250 feet above mean sea level. Eroded by the ancestral Animas and Florida Rivers, an upper bench on the bedrock surface extends over most of the central and eastern parts of the mesa; a lower bench extends along the southwestern margin of the mesa near Highway 550.

Unconsolidated sediments consisting of cobbles, gravel, sand, silt, and clay are present on numerous terraces formed by the ancestral Florida River. Detailed geologic mapping (available for the Durango East 1:24,000 quadrangle) shows terrace alluvium units Qt2 and Qt3 along the eastern margin of the Florida Mesa (See Figure 5). (This figure is presented at a zoomed-in scale and represents the southern extent of available 24K geology mapping. All other geologic mapping is based on 1:500,000 scale mapping, the best that is available.) These alluvium units are comprised of small boulders, cobbles, gravel, sand, silt, and loess. Cobble-sized clasts range from 3 to 9 inches in diameter (Carroll and others 1999). The Florida Farmers Ditch was constructed on these terrace alluvium deposits for more than 5,600 feet as the canal traverses from the Florida River valley to the Florida mesa. The boulders and cobbles in the terrace alluvium deposits can create high permeability conditions and can contribute to the development of cavities in the subsurface and slope failure of the canal embankment (Sundale Associates, Inc. 1995). These conditions could also contribute to high seepage losses within the canals.

Additional detail of geological influence on potential ditch seepage and performance is provided by the USBR in their report titled, *Florida Project Colorado – Reconnaissance Geological Report of the Farmers Ditch and Diversion Dam, May 1958* (USBR 1958). The USBR Report was prepared in advance of the planned enlargement of the Farmers Ditch. This report was prepared based on visual observation of the ditch cut bank and a geotechnical investigation was believed unnecessary. A copy of the report is provided in Appendix A.

In general, the report suggested:

1. Lining would be required in all steep slope sections and across stream gravels.

2. Shale lined sections are subject to fractures and hillside creep with numerous vertical fissures providing potential for seepage.

3. Pediment materials are conducive to providing lining materials with a 3-inch minus screen.

4. Shale formation cut slopes are stable to 1¼:1, (horizontal: vertical).

Select specific citations from the USBR Report as pertains to geologic influenced ditch permeability and related suggestions specific to lining follow (italics added for emphasis:

"Canal Geology—Detail

Station 0+00

Canal in this section is in river gravels consisting of sand, gravel, and cobbles. Some lenses of silt and clay are present but the material is permeable and the bottom of the canal is below water table during high water in the river.

Station 13+50

Canal is in a steep rock cut of Pictured Cliffs Sandstone. This rock is hard, well cemented, thin bedded, and jointed. It will require blasting and the joint system will be a source of seepage unless lined. The rock is dipping 60° southeast.

Station 18+00

Canal is in massive sandstone. This rock is hard and will require blasting and lining.

Station 21+00

Canal is in shale (Fruitland Formation) with some thin beds of coal. This shale is soft and jointed. It will require lining on the steep slopes to prevent piping and seepage through the vertical fractures. Some thin sandstone beds are interspersed in the shale."

Each of the four sections above, referenced for likely lining requirements, are within the Florida Farmers Ditch Reach G (See Figure 2). Reach G is presented later in this report as the highest priority reach for lining, based on approximate annual losses in AF per year.

2.3 Consultation with Florida Mesa Canal Company Representatives

Numerous meetings were held with the Florida Mesa Canal Companies before and after the CWCB grant was received. Meetings were conducted to:

1. Formulate the plans and objectives of the ditch loss study,
2. Identify gaging stations and measurement devices that are in need of replacement,
3. Identify canal reaches where they thought the largest losses might occur,
4. Communicate methods and approaches, and
5. Discuss preliminary results.

Meetings with the ditch riders for both the Florida Canal and Florida Farmers Ditch were extremely helpful, and their assistance with the fieldwork was essential for a successful study.

Meetings also were held with the FWCD to formulate the plans for the overall study and to help write the proposal. The history and amounts of releases from Lemon Reservoir, and the water balance calculations indicating the severity of the losses, were an important ingredient for justification of the study.

The ditch riders identified the upstream sections of the main canals as the reaches where the most losses might occur. For the Florida Canal, the greatest losses were thought to be in reaches from the headgate on the Florida River through the serpentine canyon sections to the Confluence. For the Florida Farmers Ditch, the greatest losses were thought to be in reaches from the headgate on the Florida River to the Confluence. For the Florida Farmers Ditch West, the greatest losses were thought to be in the reach just south of US Highway 160.

A follow-up visit, post ditch loss measurement was also conducted after the ditches had stopped flowing for the year and when there was no snow on the ground. The purpose of this visit was to correlate the measurement losses with a visual reconnaissance of the ditches and associated vegetation, geology, soils and morphology. The ditch company representatives also accompanied this visit. The ditch company representatives again concurred with the likelihood that the greatest losses were in the upstream ditch sections, particularly where the ditches climb out of the canyons, often along relatively steep slopes, across numerous geologic outcrops and contact planes, and through alluvial and colluvial terraces. Observations from this visit are discussed further in Prioritized Sections.

Because of time and funding limitations, several canal reaches were not included in the study. Ditches and canals not included in the study include the Florida West Ditch, Griffith Lateral, Pine Lateral (and laterals off of the Pine Lateral), and the Reservoir Ditch. Many small laterals feed off of the large canals; measurement of seepage losses from the laterals was not included in the study.

3.0 HISTORICAL DISCHARGES IN CANALS AND DITCHES

Discharge recorders have been maintained by the Colorado Division of Water Resources (DWR) for the Florida Canal headgate at the Florida River (designation FLOCANCO) and the Florida Farmers Ditch headgate at the Florida River (designation FARMERCO). Historical records for the Florida Canal are available from 1994 to the present, and records are available for the Florida Farmers Ditch from 1999 to the present (http://cdss.state.co.us/Streamflow/). Discharge recording devices have been maintained by the Florida Canal Companies for the Pine Lateral, inflow to Pastorius Lake, and the end of the Reservoir Ditch. Historical records for these ditches are available from 2005 to the present; discharge data were obtained from the Florida Mesa Canal Companies for the period covering 2005-2006.

Discharge hydrographs for the canal system show daily fluctuations related to the variability of flows in the Florida River and the changes in needs of the irrigation water users (See Figure 6). For example, the fluctuations of discharges in the Florida Farmers Ditch are shown by the same fluctuations in the Pine Lateral and inflow to Pastorius Lake (See Figure 6). The largest flows occur in the Florida Farmers Ditch; discharges in the Florida Canal are about one-third of the Florida Farmers Ditch (See Figure 6). Large diversions are taken out at the Pine Lateral, the canal then flows into Pastorius Lake, and continues south to the end of the Reservoir Ditch (See Figure 6).

These historical data are useful to observe general trends. In order to calculate ditch losses, the individual diversions from each turnout would be needed to calculate water balances. These turnout data are available in hand-written notebooks maintained by the ditch riders.

4.0 CANAL DISCHARGE MEASUREMENTS AND DITCH LOSS CALCULATIONS

4.1 Discharge Measurement Methods

In order to calculate ditch losses, canal discharge measurements were made on reaches identified as priorities by the ditch companies' representative. Discharges of diversions (laterals or agricultural withdrawals) in those reaches were documented by the ditch riders on the days of canal discharge measurements. Discharge measurements were made at 18 sites on the main canal system (Table 1). Where a flume was located in the canal, a stage reading was taken, and flume tables were used to determine discharge. Where the canals were shallow enough to be waded, the current meter (AA or Price anemometer) and wading rod were used to measure discharge. Where the canals were too deep and swift for wading measurements, the salt dilution method was used. The current meter and silt dilution methods are explained further below.

A current meter is an instrument used to measure the velocity of flowing water. The measurement of discharge by a current meter is the summation of the cross section areas of the canal multiplied by their respective average velocities.

The tracer-dilution method was used to determine discharge at sites where the canals were too deep and swift for current meter wading measurements. The method used is called the "spot-injection" method because tracer is injected and sampled within a short reach of the stream or canal. A salt solution of known concentration (saturated sodium chloride, NaCl) was injected into the canal at a constant rate using a precise pump. Water samples were collected downstream from the injection pump far enough to ensure proper mixing of salt in the reach. The discharge of the canal was determined using the conservation of mass equation:

$$Qc = QpCp/ (Cc\text{-}Cb)$$

where: Qc = unknown canal discharge,

Qp = injection-pump discharge,

Cp = injectate solute concentration (Na or Cl),

Cc = solute concentration in the canal downstream from the injection point, and

Cb = baseline solute concentration in the canal prior to the injection test.

Tracer and baseline samples were analyzed for sodium and chloride. Samples were filtered using a 0.45 micrometer capsule filter. Sodium analyses were performed using ion-selective electrode, and chloride analyses were performed using spectrophotometry. Streamflow and canal discharges using the tracer-dilution method can achieve great accuracy because of the availability of precise laboratory-quality 12-volt pumps. Maintaining an accurate, constant injection is important for obtaining a plateau of tracer concentrations in the downstream reach.

Flows being diverted from the river into the canals varied from day-to-day and week-to-week during the study. The variations of canal flows may change the relative flows of irrigation diversions down the canals, and also may change the degree of seepage loss due to different head in the canals. In order to normalize the ditch losses, discharges were made at the upstream end of a study reach for each day of work, and the ditch losses were normalized to that daily canal discharge. The length of the canal reach was measured using mapping and geographical information systems. The normalized discharges resulted in calculation of ditch loss (in cubic feet per second) per mile of canal length per cubic feet per second at the head of that reach. Discharge measurements for canals and diversions were entered into a spreadsheet, and water balances were calculated using spreadsheet methods.

4.2 Canal Discharges

Diversions from the Florida River into the canals varied during the study period. In the Florida Canal, discharges ranged from 32 to 53 cfs; in the Florida Farmers Ditch, discharges ranged from 153 to 186 cfs (See Figure 7). Discharge losses, after diversions, were then calculated for the reach in cfs, and then calculated in both a normalized loss and an annual loss in AF per year. The normalized loss was calculated in cfs (loss) per mile per cfs (flow). The annual loss in AF per year is a gross approximate calculation of the cfs loss over a 150 day irrigation season at the flow in the canal at the time of the study.

Based on the simplicity of this gross approximate calculation, these “annual losses” are not presented to indicate actual annual quantitative values, but rather an indication of the magnitude of volume that occurs under relatively high flow conditions.

The following sections describe the results of the discharge measurements, ditch losses, and observations about the canal reaches. Observations and recommendations are also provided for canal flow measurement device improvements. Figure 2 illustrates the reaches and observations discussed below.

4.2.1 Florida Canal

Discharge of the Florida Canal on July 21, 2009, at the headgate (site FC-0) was 53.1 cfs (Table 1 and Appendix B). The site is a DWR real-time gaging station (FLOCANCO), and is comprised of an 8-ft flume with culvert stilling well, strip chart recorder, shaft encoder, and satellite transmitter. Observations of the flume at the gaging station indicate a turbulent approach, which should have a stable pool above the flume, an outside staff gage should be installed, frequent cleaning for algae build up is recommended, and more frequent measurements to check shifts in the rating should be performed.

Reach A

Discharge at the next downstream station, site FC-1 (crossing under CR 234, Reach A, (See Figure 2) was 51.3 cfs. The discharge loss in the reach was 1.8 cfs, and the normalized loss was 0.070 cfs/mile/cfs. The canal Reach A is elevated above the Florida River and the banks were stabilized using rocks and concrete during the 1880s. Large cottonwood trees and willow shrubs occur between the bank of the canal and the river channel, indicating that there is plentiful water for their growth survival. The right bank of the canal is comprised of sandstone and coal of the Menefee Formation.

Reach B

Moving downstream, discharge of the Florida Canal at the Macho vehicle crossing (Reach B, See Figure 2) was 50.8 cfs, for a loss of 0.5 cfs and a normalized loss of 0.007 cfs/mile/cfs. The loss seems low for this reach, and may have been affected by unaccounted inflows from the Edgemont Ranch area. If this section is lined, the effects of inflows on the liner would require consideration.

Reach C

Discharge of the Florida Canal on July 22, 2009, at Horse Gulch (site FC-3) was 46.0 cfs, with diversions of 1.25 cfs between FC-2 and FC-3. There was a loss of 4.1 cfs in this Reach C (See

Figure 2), and a normalized loss of 0.078 cfs/mile/cfs. The canal flows past the outcrop of the Pictured Cliffs Sandstone through this reach. The fractured nature of the sandstone and the type of local material available for construction of the canal through this reach may contribute to the large loss. The discharge measurement site was upstream from the Horse Gulch crossing; therefore, Horse Gulch losses (obvious from seepage along the Horse Gulch road) were accounted for in the next reach.

Reach D

Discharge of the Florida Canal at the Busby property (site FC-4) was 45.3 cfs, with no diversions in this Reach D (See Figure 2). The discharge loss was 0.7 cfs, and the normalized loss was 0.007 cfs/mile/cfs. Most of the loss was probably in the Horse Gulch crossing. After Horse Gulch, the canal is located on shale bedrock, and the canal is not elevated above the valley as in previous reaches; therefore, the canal has shale banks from Horse Gulch to the Busby property.

Reach E

Discharge of the Florida Canal near Squaw Apple Road (site FC-5) was 43.7 cfs, with diversions of 0.4 cfs in Reach E (See Figure 2). The discharge loss was 1.3 cfs, and the normalized loss was 0.018 cfs/mile/cfs. Most of the loss in Reach E probably occurs as the canal serpentines through Payne Canyon (See Figure 2). Observations reported by Justin Catalano (Ditch Rider for the Florida Canal), the flows from Payne Canyon begin about one month after water is let into the Florida Canal, indicating that the canal bed and banks take a while to become saturated.

Reach F

Discharge of the Florida Canal at the Confluence (site FC-6) was 30.0 cfs, with diversions of 14.3 cfs in Reach F. The discharge loss was shown as negative in the reach; however, this is reflected in two observations: (1) there were irrigation return flows in the reach, and (2) the flume for the Florida West Canal does not read accurately.

To summarize the Florida Canal, the greatest discharge losses occurred in Reach C between site FC-2 and FC-3 where the canal crosses the Pictured Cliffs Sandstone. The ditch companies have been applying polyacrylamide (PAM) to many reaches of the Florida Canal, and this has made dramatic improvements to the seepage losses observed compared to prior to the PAM applications. However, the PAM cannot seal large leaks, such as fractures in sandstone. The Parshall flume at the Florida West Canal diversion has been submerged due to road construction at CR 234. The flume should be replaced, or another measuring device (such as a Cipoletti weir or compound V-notch weir) could be put in the place of the Parshall flume. The discharge for the Florida Canal at the Confluence (site FC-6) was determined using the standard rating table for a 5-foot Parshall flume; however, the structure is not a Parshall flume, but it is a concrete drop structure with a turbulent approach. Check measurements could be made at this flume to calibrate the accuracy of the standard flume table.

4.2.2 Florida Farmers Ditch

Discharge of the Florida Farmers Ditch on July 14, 2009, at the headgate (site FFC-0) was 157.0 cfs (Table 1 and Appendix C). The site is a DWR real-time gaging station (FARMERCO), and is comprised of a 10-ft flume with culvert stilling well, strip chart recorder, shaft encoder, and satellite transmitter. The inside and outside staff gages do not agree; therefore, the standard rating table for a Parshall flume is not a reliable source of information regarding discharge at this site. The DWR has made seven discharge measurements over three years to check and calibrate the accuracy of the rating for this site; the measurements have resulted in significant shifts to the rating. Therefore, it is uncertain whether the flume is settling, or the recorder shelter (culvert stilling well) is unstable. Levels need to be run at the gaging station to correct the difference between the inside and outside staff gages, and the flume should be checked for trueness.

Reach G

Discharge of the Florida Farmers Ditch below the Payne Canyon siphon (site FFC-1) was 143.3 cfs, with diversions of 0.5 cfs in Reach G (See Figure 2). The discharge loss was 13.2 cfs, and the normalized loss was 0.055 cfs/mile/cfs. Most of the loss in Reach G probably occurs near Palmer Quarter Horse Ranch where CR 234 crosses the Florida River.

Reach H

Discharge of the Florida Farmers Ditch at CR 236 (site FFC-2) was 131.0 cfs, with diversions of 3.5 cfs in Reach H. The discharge loss was 8.8 cfs, and the normalized loss was 0.050

cfs/mile/cfs. The canal crosses quaternary gravels along the margin of the mesa in Reach H, and most of the losses probably occur through these gravels.

Reach I

Discharge of the Florida Farmers Ditch at the Confluence (site FFC-3) was 124.0 cfs, with diversions of 10.25 cfs in Reach I. The discharge loss was shown as negative. There are two possible reasons for the negative ditch loss; 1) irrigation return flows and 2) flow measurement error at the end of the reach (FFC-3). WWE identified irrigation return flows accruing to Reach I. The rating for a 12-ft Parshall flume was used to determine discharge at this site; however, the structure is not a Parshall flume, but it is a drop structure with narrowing throat width. The "12-ft" concrete structure at the Confluence is actually 11-ft, 11-inches wide, which might affect the rating.

To summarize the Florida Farmers Ditch, the reach from the headgate to the Confluence (Reaches G, H and I) carries more water than any other canal in the study area. The large head in the canal, and the elevation of the canal above the Florida River, contribute to the relatively large losses. There was a section below Payne Canyon that had large seepage, and caused the canal bank to collapse during the 1980s. This section has been repaired; however, this bank failure is indicative of the large heads on the canal and the materials available for the original construction of the canal. The section below Payne Canyon was constructed using local material, which is comprised of terrace alluvium. This terrace alluvium contains small pebbles and cobbles (3 to 9 inches), it has a silty matrix, and is capped by 5 feet of fine-grained loess (wind-blown deposit) (Carroll and others 1999).

4.2.3 Florida Canal South

Reach J

Discharge in the Florida Canal South (Reach J, Figure 2) on July 30, 2009, below the Confluence (site FCS-1) was 163.0 cfs (Table 1 and Appendix D). Discharge in the Florida Canal South above CR 172 (site FCS-2) was 101.7 cfs. There are many diversions in Reach J totaling 60.82 cfs, and including the Pine Lateral. However, the accuracy of the Pine Lateral diversion (55 cfs) was uncertain. The calculated discharge loss in the reach was a relatively low 0.52 cfs, and the normalized loss was 0.006 cfs/mile/cfs.

Reach K

Discharge in the Florida Canal South at Pastorius Lake (site FCS-3) was 87.9 cfs, with diversions of 9.3 cfs in Reach K. The discharge loss was 4.51 cfs, and the normalized loss was 0.017 cfs/mile/cfs. The theoretical rating for the ramp flume at FCS-3 was 85 cfs. There may have been return flows from irrigated agriculture entering this reach.

To summarize the Florida Canal South, there are numerous diversions through the reach between the Confluence and Pastorius Lake. The diversion accuracies are uncertain; therefore, to perform water balances in the future, discharge in measuring devices for the diversions need to be curtailed temporarily or checked for accuracy.

4.2.4 Florida Farmers Ditch West

Discharge in the Florida Farmers Ditch West on July 29, 2009, below the Confluence (site FFW-1) was 36.0 cfs (Table 1 and Appendix E). The ramp flume at this site indicated a discharge of 55 cfs, and does not measure correctly. Levels need to be run to establish inside and outside staff gages for this gaging station, and a rating needs to be developed for the ramp flume.

Reach L

Discharge in the Florida Farmers Ditch West above US Highway 160 (site FFW-2) was 27.3 cfs, with diversions of 3.3 cfs in Reach L (See Figure 2). The discharge loss was 5.4 cfs, and the normalized loss was 0.061 cfs/mile/cfs. Most of the losses probably occur near the end of the reach where there is a steep gradient toward Highway 160 and into the Grandview area.

Reach M

Discharge in the Florida Farmers Ditch West below Grandview (site FFW-3) was 16.4 cfs, with diversions of 8.25 cfs in Reach M. The discharge loss was 2.6 cfs, and the normalized loss was 0.059 cfs/mile/cfs. Most of the losses that occur throughout this reach are due to the steep gradient into the Grandview area.

Reach N

Discharge in the Florida Farmers Ditch West above Pastorius Reservoir (site FFW-4) was 3.3 cfs, with diversions of 15.5 cfs in Reach N. The discharge loss was shown as negative due to possible irrigation return flows in the reach or problem with measuring the numerous diversions in this reach.

To summarize the Florida Farmers Ditch West, most of the losses occur as the canal is routed around the Grandview area (Reach M). Charlie McCoy (Ditch Rider for the Florida Farmers Ditch) indicated that there is seepage all the way along the banks of Reach M. The Falfa Clay Loam that comprises the soil along this reach should be an adequate construction material for ditches and canals; however, freeze-thaw during the winter and creeping soil could contribute to leaks in the canal banks.

5.0 PRIORITIZED SECTIONS

The canal reaches described in this report were studied because they carry the largest volumes of water, and are subject to the largest seepage losses due to the heads in these large canals. The reaches need to be prioritized in order to focus rehabilitation efforts on the largest losses. Specific reaches and methods to repair and rehabilitate the losses will be addressed in future efforts by the Florida Mesa Canal Companies.

There are two ways to rank and prioritize the reaches for more detailed investigations and remediation 1) according to normalized losses, where the loss was divided by the length of the canal reach, and then divided by the discharge of the canal at the head of that reach, and 2) according to annual losses calculated in AF per year (Table 2).

According to normalized losses, the largest proportionate losses occurred in the Florida Canal from the Macho Crossing to Horse Gulch (Reach C, Figure 2, Table 2). Similar losses may have actually occurred in Reach B (CR 234 to Macho crossing); however, inflows may have occurred in that reach negating any calculated losses. The next highest normalized loss ranking reaches were Reach A (Florida Canal), Reach L (Florida Farmers Ditch West), Reach M (Florida

Farmers Ditch West), Reach G (Florida Farmers Ditch), and Reach H (Florida Farmers Ditch) (See Table 2).

According to annual losses in AF per year (i.e., the approximate sheer volume of water), the largest loss occurred in the Florida Farmers Ditch from the headgate to the Payne Canyon siphon (Reach G, Table 2). Large annual losses also occurred in Reach H (Florida Farmers Ditch), the next reach downstream from Payne Canyon. The next highest ranking in annual losses occurred in Reach L (Florida Farmers Ditch West), then Reach K (Florida Canal South), Reach C (Florida Canal), Reach M (Florida Farmers Ditch West), and Reach A (Florida Canal) (Table 2). These annual losses in AF per year and AF per year per mile are in Table 3.

Large annual losses were also calculated in the Florida Canal from the headgate to CR 234 and from the Macho property to Horse Gulch.

To further refine the canal reaches and lengths specifically recommended for lining, additional field observations were conducted. These observations were made with Florida Mesa Canal Companies representatives while the ditches were dry and there was no snow on the ground. High loss canal sections were observed for permeability characteristics including surrounding geology, soils, lining materials, terraces, fractures, evidence of seeps, vegetation, etc.

The focus of this visit became the Florida Farmers Ditch from the measurement flume to CR 236 as the largest loss reaches, Reaches G and H. These two reaches are also good lining candidate sections due to the ease of vehicle and heavy construction access. For the opposite reasons, lack of vehicle access for construction equipment, inadequate maintenance access road, and possibly the need for additional easement, the upper reaches of the Florida Canal became a lower priority for lining.

The first section of the Florida Farmers Ditch, above the measurement flume and below the diversion structure is located in the Florida River valley floodplain. This reach is in the river alluvium subject to a high groundwater table and is therefore not a good lining candidate reach. Downstream of the flume, the canal crosses the 60° inclined outcrops, progressively, of the Pictured Cliffs Sandstone, Fruitland Formation, Kirtland Shale, and Animas Formation and then traverses the mesa into the Falfa Clay Loam. As the ditch traverses the canyon wall, the more permeable sandstones, joint systems and fractures, and alluvial and colluvial terraces are all sources of ditch loss.

Vegetation along the canyon walls, on the downhill side of the ditch, often includes cottonwoods, suggesting leaks from the ditch. Away from the ditch, the vegetation is more commonly Gambel oak and Ponderosa pine, indicative of a drier environment.

Based on results of these observations, further engineering work will be performed for the recommended lining reaches.

6.0 MEASURING DEVICES

Many of the flumes and measuring devices in the Florida Canal system are not reading accurately. Many of the measuring devices were installed decades ago, and they have not been checked for accuracy. In theory, the Parshall flumes are installed level and true, they should be accurate for their life of service. However, this may not be the case when the flumes may settle due to freeze-thaw or there is erosion under and around the flume. Concrete structures were installed at the Confluence by the USBR in the 1960s; however there is no information regarding the theoretical ratings for these flumes and they have not been checked for accuracy.

The flumes at the headgates for the Florida Canal and Florida Farmers Ditch are being serviced by the Colorado Division of Water Resources (DWR). Accurate discharges for these intake structures are important for efficient use of water on the Florida Mesa. More frequent servicing could ensure that these measuring devices are providing the most accurate information. Levels need to be run to the staff gages, the level and trueness of the concrete flumes needs to be checked, and the discharges need to be verified on a regular basis.

7.0 REFERENCES CITED

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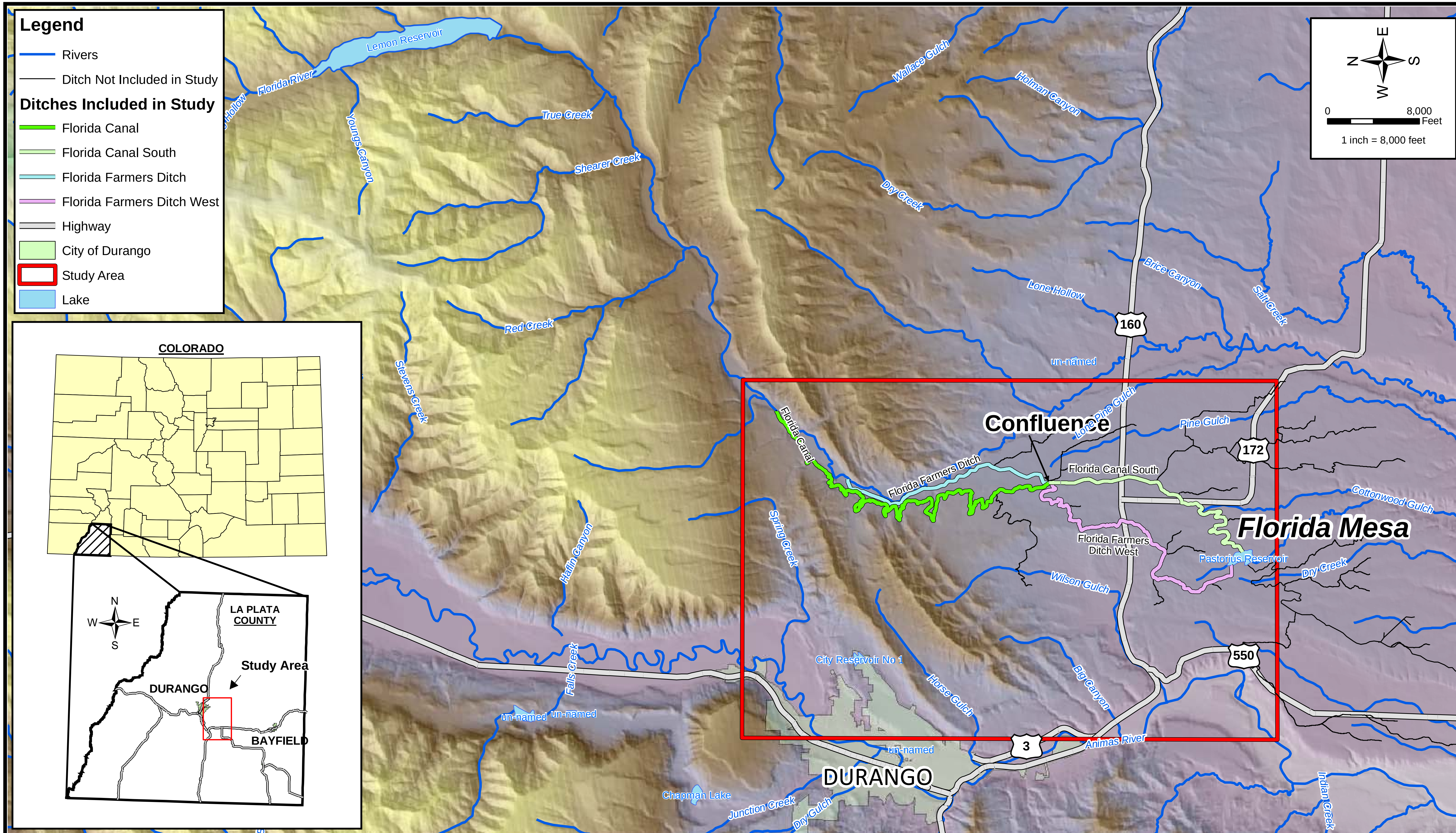
Sundale Associates, Inc., 1995, Florida Farmers Ditch-Payne Canyon Slide Investigation, 13 p.

FIGURES



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LA PLATA COUNTY, COLORADO

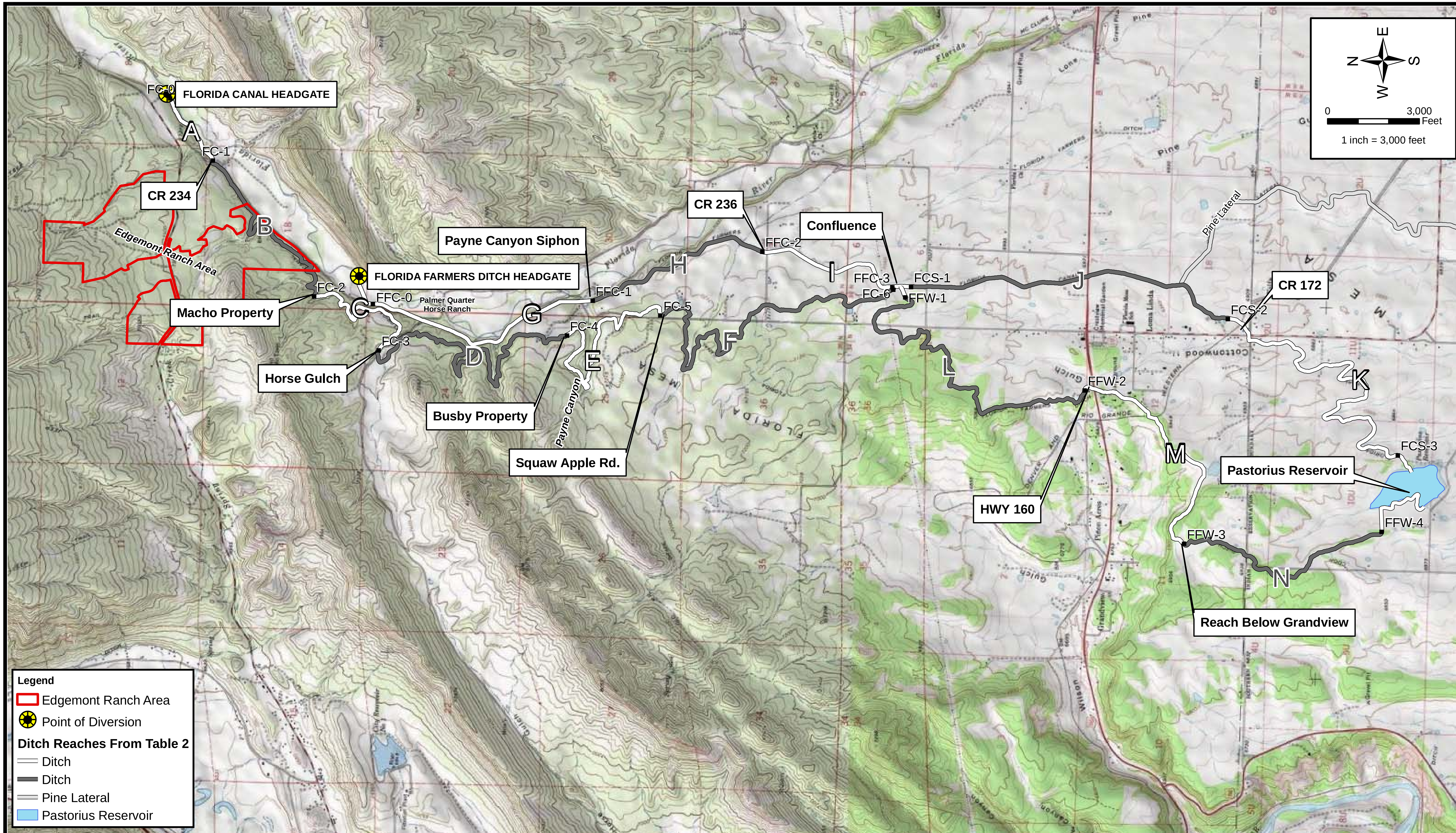
LOCATION MAP

FLORIDA MESA CANAL COMPANIES' WATER LOSS REDUCTION PROJECT

Project No.

061-110.041

FIGURE
1



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DITCH REACH LOCATION DESCRIPTIONS

FLORIDA MESA CANAL COMPANIES' WATER LOSS REDUCTION PROJECT

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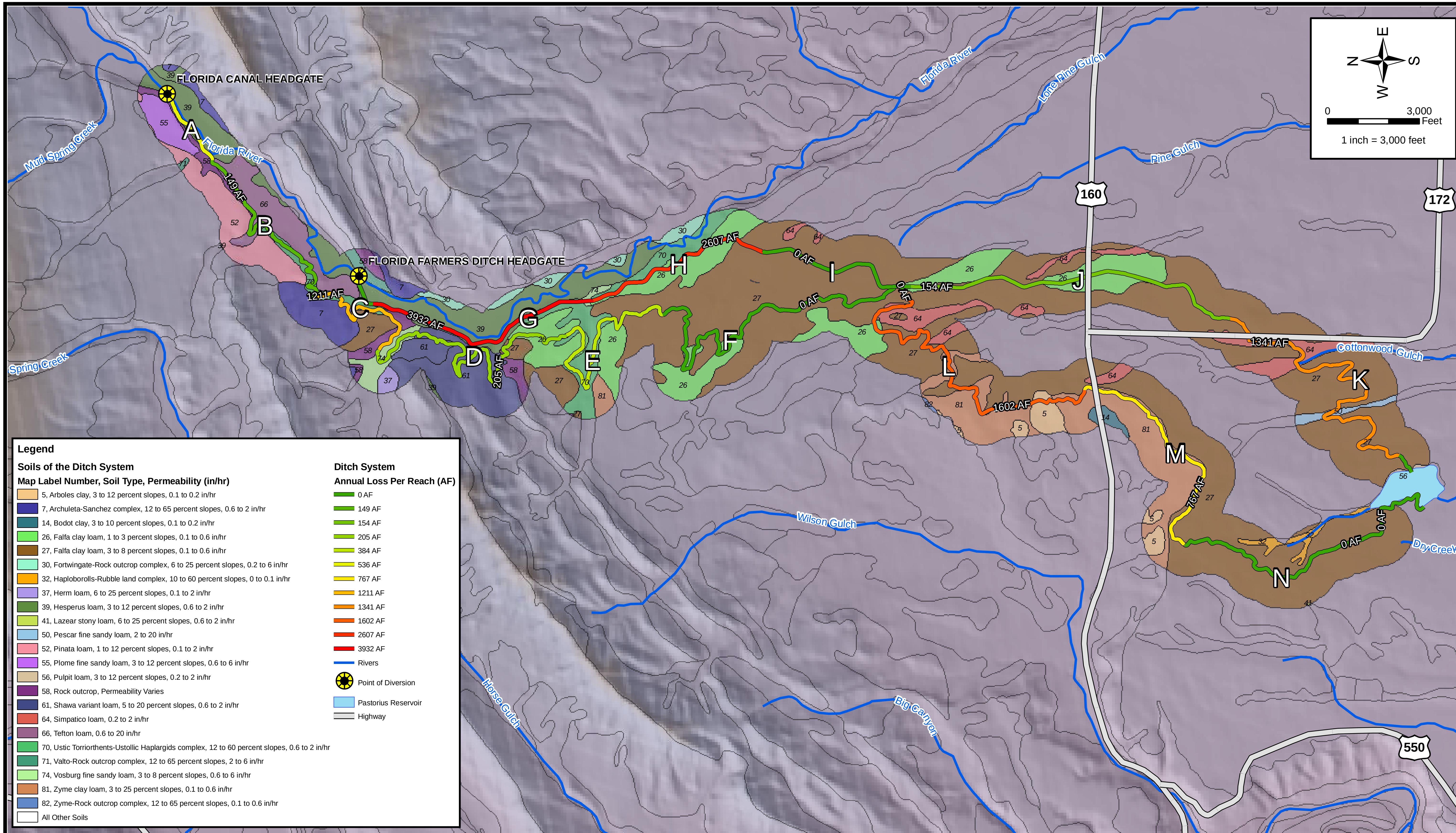
FIGURE 2



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DITCH LOSS PER REACH AND SOILS MAP

FLORIDA MESA CANAL COMPANIES' WATER LOSS REDUCTION PROJECT

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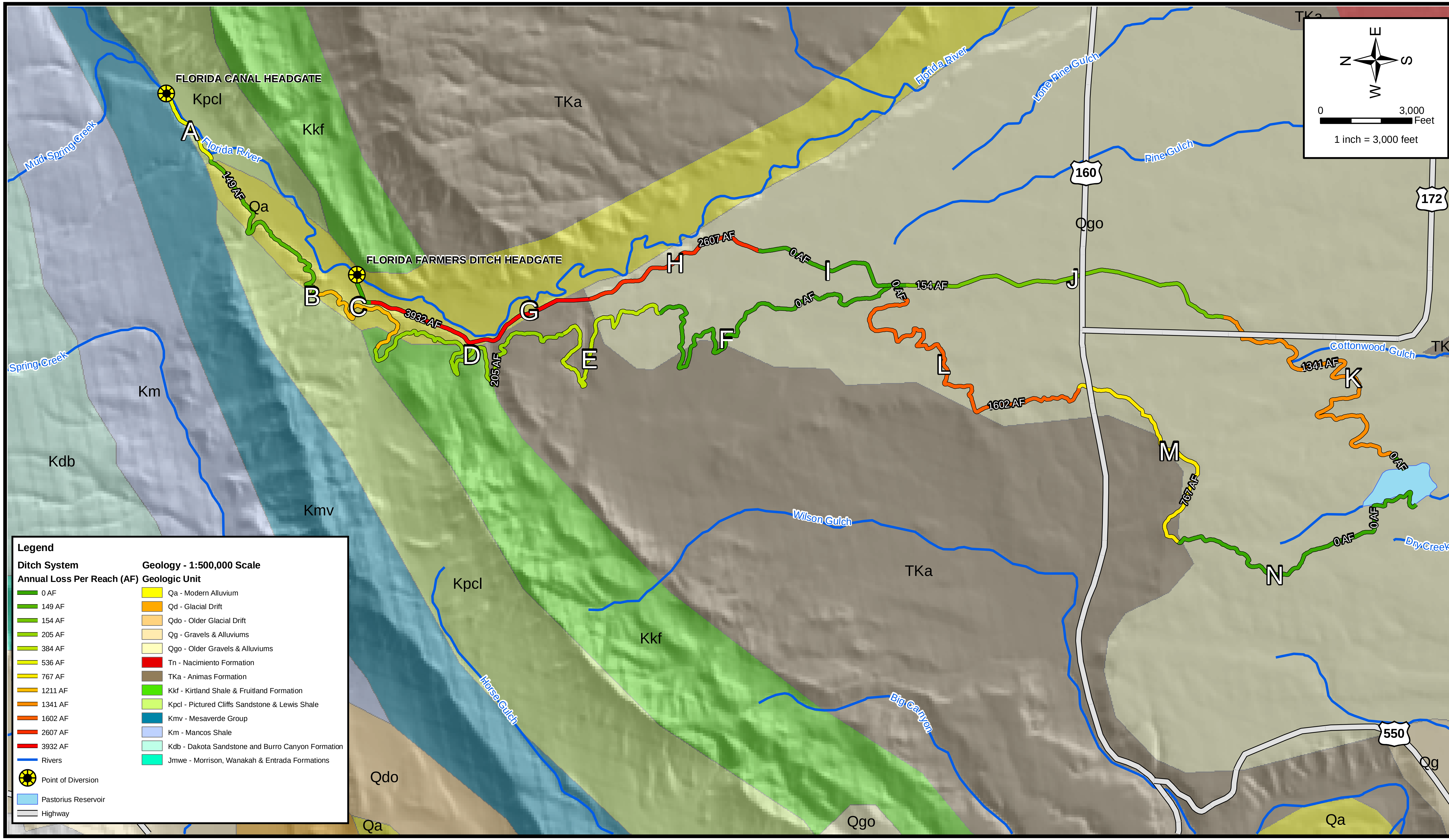
FIGURE 3



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Geology: 1:500,00 scale, Geologic Map of Colorado

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DITCH LOSS PER REACH AND GEOLOGY MAP

FLORIDA MESA CANAL COMPANIES' WATER LOSS REDUCTION PROJECT

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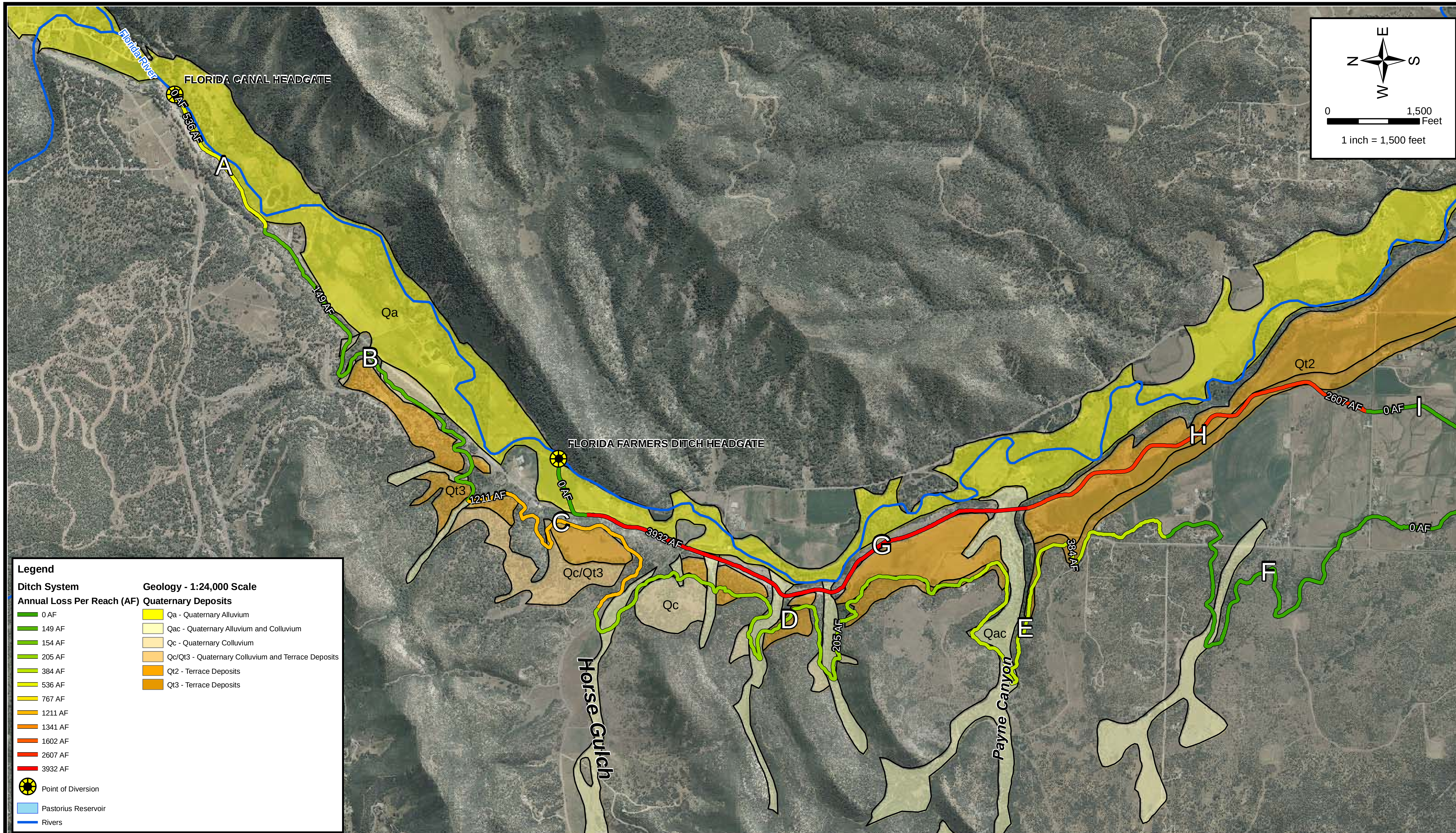
061-110.041

FIGURE 4



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Geologic Map: 1:24,000 Scale, Durango East Quadrangle, 24K scale mapping used where available.

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QUATERNARY GEOLOGY - ALLUVIAL AND COLLUVIAL DEPOSITS

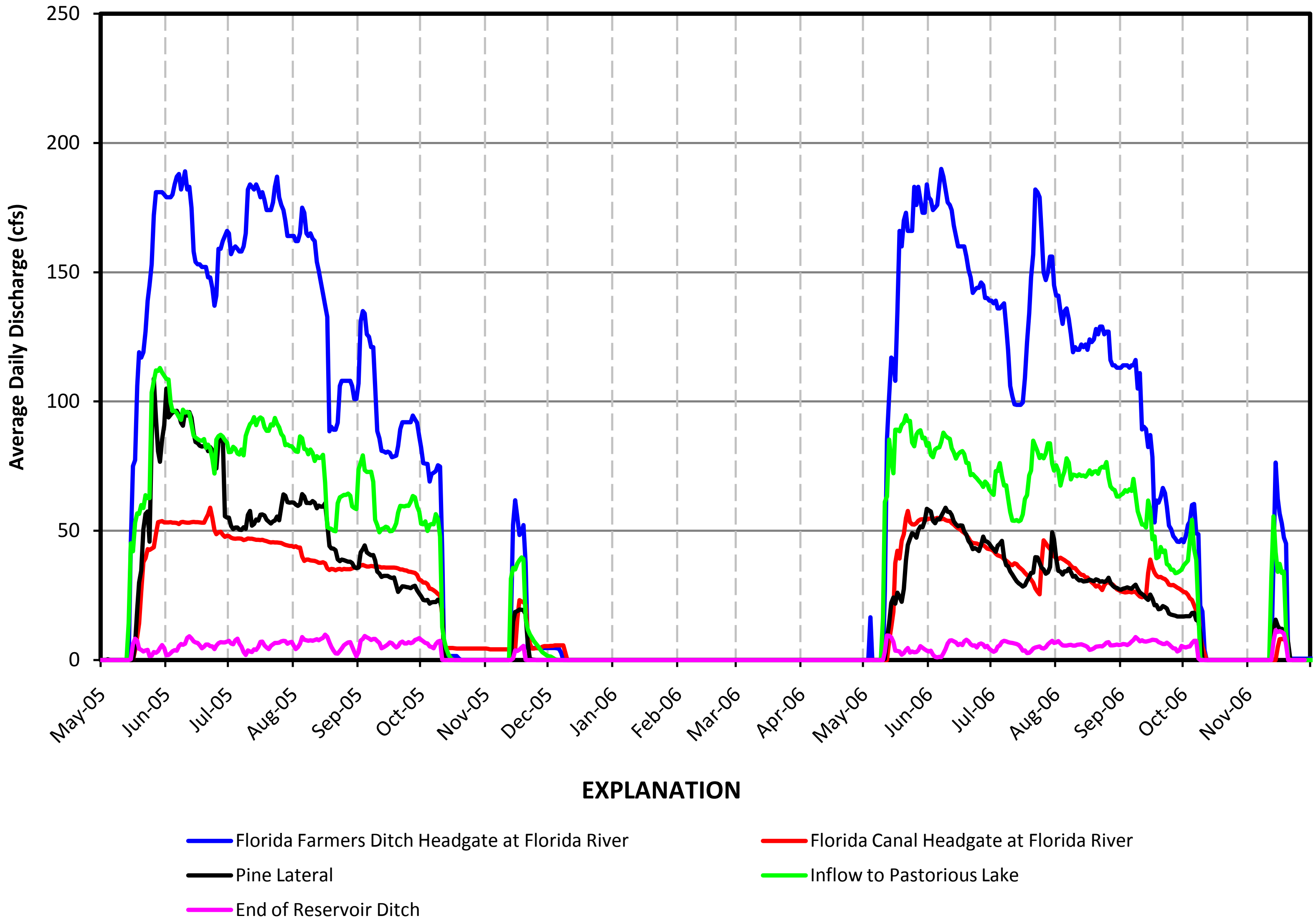
FLORIDA MESA CANAL COMPANIES' WATER LOSS REDUCTION PROJECT

Project No. 061-110.041

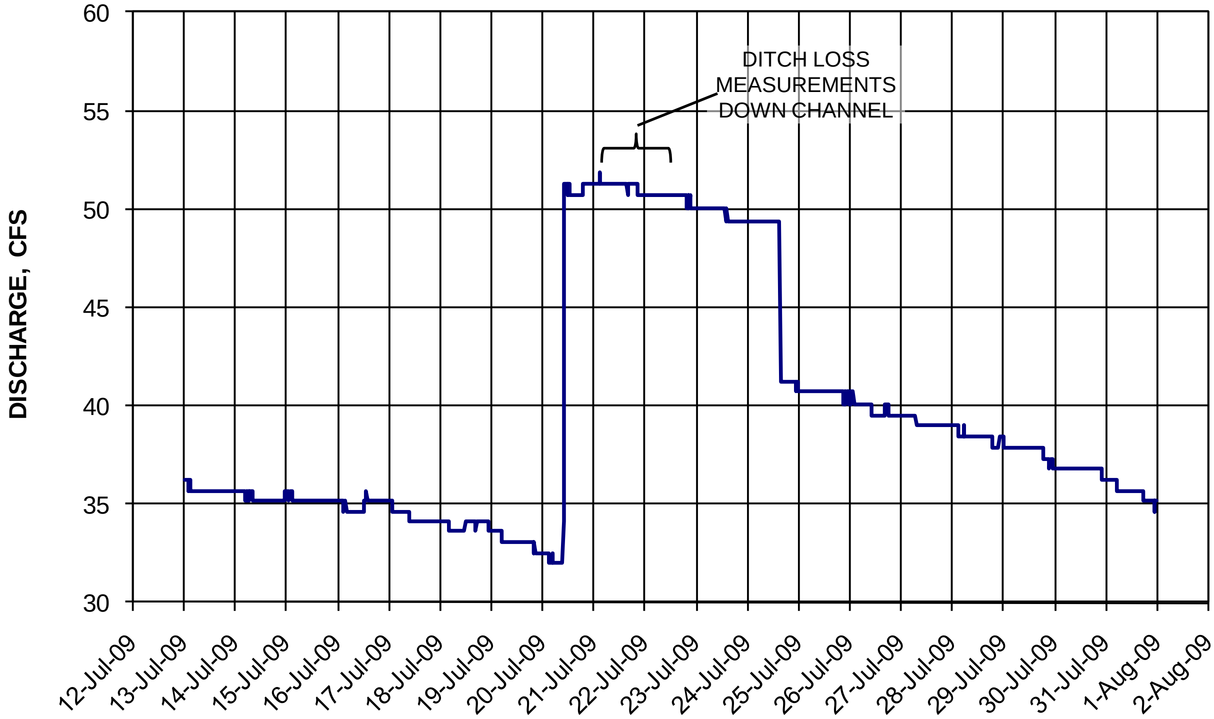
FIGURE 5

FIGURE 6

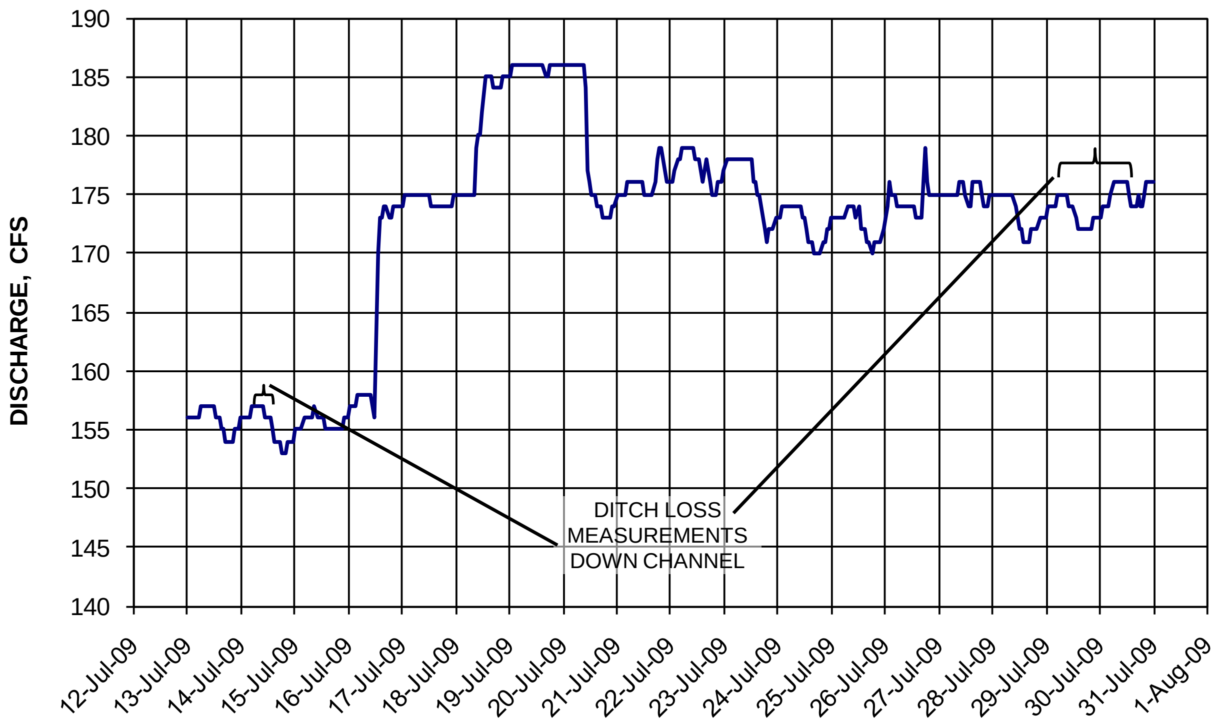
Discharge Hydrographs of Canals and Ditches, 2005-06



FLORIDA CANAL--DISCHARGES AT HEADGATE DURING STUDY PERIOD



FLORIDA FARMERS DITCH--DISCHARGES AT HEADGATE DURING STUDY PERIOD



WWE WRIGHT WATER ENGINEERS INC. 1666 N. MAIN AVE., SUITE C DURANGO, CO 81301	Hydrographs for the Florida Canal and Florida Farmers Ditch During Study Period	PROJECT NO. 061-110.040	FIGURE 7

TABLES

Table 1

Sites for the Florida Mesa ditch loss study, discharges, normalized losses, and annual losses

[UTM_X, Easting meters NAD83; UTM_Y, Northing meters NAD83; ft, feet; cfs, cubic feet per second; acre-ft/yr, acre-feet per year; --, beginning of reach or inconclusive results]

Site Name	Site Description	UTM _X	UTM_Y	Altitude, ft	Date Time	Discharge, cfs	Diversions In Reach, cfs	Error, ±cfs	Discharge Loss In Reach, cfs[a]	Reach Length, miles	Normalized Loss, cfs/mile/cfs	Annual Loss in Reach, acre-ft/yr[b]
FC-0	Florida Canal at headgate	254293	4133153	7,204	7/21/09 12:40	53.1	--	4	--	--	0	--
FC-1	Florida Canal at CR234	253675	4132728	7,195	7/21/09 9:00	51.3	0	4	0.070	0.481	0.07	536
FC-2	Florida Canal at Macho crossing	252323	4131718	7,181	7/21/09 10:30	50.8	0	4	0.500	1.402	0.007	149
FC-3	Florida Canal at Horse Gulch	251786	4131072	7,177	7/22/09 10:45	45.9	1.25	1	4.070	1.025	0.078	1,211
FC-4	Florida Canal at Busby property	251932	4129195	7,158	7/22/09 12:30	45.3	0	1	0.690	2.284	0.007	205
FC-5	Florida Canal near Squaw Apple Rd	252132	4128263	7,144	7/22/09 13:40	43.6	0.35	1	1.290	1.599	0.018	384
FC-6	Florida Canal at Confluence	252389	4125942	7,052	7/22/09 16:00	30	14.25	1	-0.600	2.599	-0.005	--
FFC-0	Florida Farmers Canal at headgate	252246	4131128	7,122	7/14/09 12:00	157	--	5	--	--	0	--
FFC-1	Florida Farmers Canal below Payne Canyon siphon	252279	4128938	7,065	7/14/09 10:00	143.2	0.5	3	13.216	1.518	0.055	3,932
FFC-2	Florida Farmers Canal at CR236	252766	4127246	7,058	7/14/09 13:00	131	3.5	3	8.762	1.233	0.05	2,607
FFC-3	Florida Farmers Canal at Confluence	252413	4125950	7,051	7/14/09 13:40	124	10.25	6	-3.228	0.952	-0.026	--
FCS-1	Florida Canal South below Confluence	252418	4125765	7,038	7/30/09 9:50	163.0	--	2	--	--	0	--
FCS-2	Florida Canal South above CR 172	252096	4122604	6,911	7/30/09 13:45	101.7	60.8	2	0.517	0.006	0.006	154
FCS-3	Florida Canal South at Pastorius Lake inlet	250741	4120910	6,852	7/30/09 12:15	87.9	9.3	3	4.507	2.656	0.017	1,341
FFW-1	Florida Farmers West below Confluence	252314	4125822	7,045	7/29/09 10:30	35.9	--	1	--	--	0	--
FFW-2	Florida Farmers West above US Hwy 160	251385	4124032	6,967	7/29/09 15:30	27.2	3.3	1	5.386	2.467	0.061	1,602
FFW-3	Florida Farmers West below Grandview	249859	4123040	6,924	7/29/09 13:40	16.4	8.25	1	2.577	1.590	0.059	767
FFW-4	Florida Farmers West at Pastorius Lake inlet	249978	4121069	6,853	7/29/09 12:30	3.3	15.45	5	-2.333	1.482	-0.096	--
								Total estimated annual losses, acre-ft/yr				**12,887**

[a] Negative loss indicates discharge gain through reach due to irrigation return flows

[b] Annual losses calculated for 150 days of irrigation season per year at the canal flows occurring during the study

Table 2

Prioritization of reaches for the Florida Mesa ditch loss study

[cfs, cubic feet per second; acre-ft/yr, acre-feet per year; --, inconclusive result]

Reach Name	Canal Name	Reach Description	Site Names	Discharge Loss In Reach, cfs	Normalized Loss, cfs/mile/cfs	Prioritization Rank by Normalized Loss	Annual Loss in Reach, acre-ft/yr	Prioritization Rank by Acre-ft/yr Loss
A	Florida Canal	Florida Canal Headgate to CR234	FC-0 to FC-1	0.07	0.070	2	536	7
B		CR234 to Macho property	FC-1 to FC-2	0.5	0.007	9	149	11
C		Macho property to Horse Gulch	FC-2 to FC-3	4.07	0.078	1	1211	5
D		Horse Gulch to Busby property	FC-3 to FC-4	0.69	0.007	10	205	9
E		Busby property to Squaw Apple Rd	FC-4 to FC-5	1.29	0.018	7	384	8
F		Squaw Apple Rd to Confluence	FC-5 to FC-6	--	--	--	--	--
G	Florida Farmers Canal	Florida Farmers Canal headgate to Payne Canyon siphon	FFC-0 to FFC-1	13.2	0.055	5	3932	1
H		Payne Canyon siphon to CR236	FFC-1 to FFC-2	8.8	0.050	6	2607	2
I		CR236 to Confluence	FFC-2 to FFC-3	--	--	--	--	--
J	Florida Canal South	Florida Canal South below Confluence to CR172	FCS-1 to FCS-2	0.52	0.006	11	154	10
K		CR172 to Pastorius Reservoir	FCS-2 to FCS-3	4.5	0.017	8	1341	4
L	Florida Farmers West Canal	Florida Farmers West Canal from Confluence to US Hwy 160	FFW-1 to FFW-2	5.4	0.061	3	1602	3
M		US Hwy 160 to reach below Grandview	FFW-2 to FFW-3	2.6	0.059	4	767	6
N		Grandview to Pastorius Reservoir	FFW-3 to FFW-4	--	--	--	--	--

Table 3

Annual Losses Summary

Reach I.D.	Canal	Location	Annual Losses in Acre-Feet/Year	Length (miles)	Acre-Feet/Mile
G	Florida Farmers Ditch	Headgate to Payne Canyon	3,932	1.5	2,620
H	Florida Farmers Ditch	Payne Canyon downstream	2,607	1.2	2,170
L	Florida Farmers West	Confluence to Highway 160	1,602	2.5	640
K	Florida Canal South	CR 172 to Pastorius	1,341	2.7	500
C	Florida Canal	Macho property to Horse Gulch	1,211	1.0	1,200
M	Florida Farmers West	Highway 160 to below Grandview	767	1.6	480
A	Florida Canal	Headgate to CR 234	536	0.5	1,070

APPENDIX A
Reconnaissance Geological Report of the Farmers Ditch And Diversion Dam

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

FLORIDA PROJECT
COLORADO

Reconnaissance Geological Report
of the
Farmers Ditch and Diversion Dam

G-117

Region 4
Salt Lake City, Utah

May 1958

CONTENTS

Project Development Division
Geology Branch
Salt Lake City, Utah
May 1958

Report No. G-117
Written by:
J. Neil Murdock

Subject: Reconnaissance Geological Report of the Farmers Ditch and Diversion Dam--Florida Project, Colorado

Location

The Farmers Ditch is an existing canal built by private interests which furnishes water to irrigators on lands in the proposed Florida Project area. Present plans contemplate storage at the Lemon dam site and enlargement of the present Farmers Ditch to irrigate additional lands west of the Florida River.

The Farmers Ditch is diverted by a concrete diversion dam and after crossing the Florida stream valley it climbs slowly up the right side of the valley along a hillside slope which varies from gentle to very steep. The length of the existing ditch is 26,000 feet, the last two miles of which are within the flat bench lands which form the cultivated farms.

Scope of this report

It is the intent of this report to present the general geologic conditions which will prevail when the excavation is made to enlarge the canal. Information was secured by traversing the existing ditch on foot without the benefit of subsurface exploration. It is believed, however, that no exploration will be required since the cutbank of the ditch gives an accurate and complete exposure of the material to be encountered.

General Geology

The canal is in the foothills of the San Juan Mountains. Florida River heads on the south slope of the range and runs in a southerly course to its confluence with the Animas near Bondad. Upwarping of the sedimentary rocks along the flank of the San Juan has exposed all the strata ranging in age from Paleozoic to Tertiary. The Florida River follows the pattern of the other streams and follows the strike of the beds in the soft shale and cuts straight down-dip on the more resistant sandstone. The dip of the beds along the line ranges from nearly flat at the lower end of the canal to about 60 degrees south at the upper end. The strike is N. 60° east. All the beds involved in the canal are either Cretaceous or Tertiary in age. The following formations were examined: Lewis shale, Picture Cliff sandstone, Fruitland formation, Kirtland shale, McDermott formation, and Animas formation.

Glaciers occupied the headwaters of all the major streams in the San Juan, and the Florida was no exception. The ice, however, did not reach the

area embraced by this report but the stream carried the outwash gravels which make up much of the stream fill in the channel.

Diversion Dam Geology

The existing diversion dam is constructed along the left or east side of the stream valley where the river is flush against a steep slope. The left abutment and overflow chute is founded on sandstone which shows little or no effect of erosion. This structure has operated for many years with a minimum of maintenance. The sandstone dips downstream 60° and strikes north 60° east. It belongs to the Picture Cliff sandstone formation. It is structurally sound and competent to support any enlargement contemplated here.

The right side of the diversion structure rests on stream fill of sand, gravel, and boulders estimated to be a maximum of 50 feet deep which extends across the entire channel, a distance of 600 or 700 feet. These deposits are typical river fill of well rounded, well graded sand, gravel, and boulders with varying amounts of silt. This material probably is more or less permeable but offers no serious problems to a low diversion structure.

Canal Geology--General

Excavation along the canal will be practically all common. Only about 1,000 feet will be in a rock excavation which will require blasting. The slopes appear to be stable and the existing canal has operated with no serious trouble from landslides.

Lining probably will be required in all the sections where the slopes are steep and across the stream gravels. Even though the shales are impervious when undisturbed, fractures and hillside creep has opened up numerous vertical fissures near the surfaces and these are a potential source of seepage. The pediment material is well suited to canal lining material if the large oversize boulders(plus 3") are screened out. This material is plentiful and is well graded from clay through silt, sand, and with some fine gravel.

Cut slopes in the shale will stand on 1 1/4:1 slopes without excessive maintenance.

Canal Geology--Detail

Station 0+00

Canal in this section is in river gravels consisting of sand, gravel, and cobbles. Some lenses of silt and clay are present but the material is permeable and the bottom of the canal is below water table during high water in the river.

Station 9+00

This section of the canal is in the Lewis shale which is a soft dark carbonaceous sediment which weathers rapidly to a fat clay. Dip is 60 degrees southeast.

Station 13+50

Canal is in a steep rock cut of Picture Cliff sandstone. This rock is hard, well cemented, thin bedded, and jointed. It will require blasting and the joint system will be a source of seepage unless lined. The rock is dipping 60° southeast.

Station 18+00

Canal is in massive sandstone. This rock is hard and will require blasting and lining.

Station 21+00

Canal is in shale (Fruitland formation) with some thin beds of coal. This shale is soft and jointed. It will require lining on the steep slopes to prevent piping and seepage through the vertical fractures. Some thin sandstone beds are interspersed in the shale.

Station 27+50

Canal is in massive sandstone and well consolidated siltstone. (Kirtland formation.) This will require blasting. Overflow structure at 28+00.

Station 28+00

Canal is in soft dark carbonaceous shale (Kirtland formation) with a few thin (1') beds of sandstone. This formation can be excavated without blasting.

Station 40+00

Canal is in alternating sandstone and shale. This rock is dipping 35 degrees southeast. It is soft and can be easily excavated without blasting.

Station 45+50

Canal is in overburden materials consisting of silt, sand, and well rounded cobbles with sufficient clay for a binder. This material stands well and makes a good canal bank. There is sufficient clay to hold the mass together and the cobbles prevent excessive erosion. This material is impervious and will not require lining.

Station 47+00

The canal is in alternating sandstone and shale. This rock is soft and easily excavated.

Station 48+00

The canal is in soft sandstone with clay seams.

Station 52+25

The canal is in soft shale.

Station 54+50

The canal is in soft sandstone.

Station 57+00

Canal is in overburden (old pediment surface) consisting of clayey sand with some cobbles.

Station 58+50

Canal is in soft sandstone.

Station 60+00

Canal is in overburden consisting of clayey sand with some gravel.

Station 62+00

Canal is in soft sandstone with some shale beds.

Station 63+00

Canal is in soft shale.

Station 64+40

Canal is in a steep cliff of soft sandstone with a few thin beds of shale. Rock will stand on a 1/2 to 1 slope and can be excavated without blasting.

Station 71+00

Canal is in a boulder conglomerate.

Station 73+00

Canal is in a soft sandstone.

Station 76+00

Canal is in alternating beds of soft sandstone and red shale. Rock dips about 13° southeast (McDermott formation).

Station 84+00

Overburden of clayey sand.

Station 85+00

Canal is in boulder conglomerate.

Station 87+00

Canal is in clayey sand overburden.

Station 88+00

Canal is in tan-colored shale containing many vertical fractures.

Station 92+00

Canal is in conglomerate and shale. The conglomerate is well cemented.

Station 97+00

Canal is in red-green shale. This material is soft and easily weathered.

Station 97+60

Canal is in boulder conglomerate.

Station 98+50

Canal is in soft shale.

Station 100+00

Canal is in overburden consisting of clay and cobbles.

Station 101+00

Canal is in alternating soft sandstone and shale. Rock is horizontal and belongs to the Animas formation.

Station 105+00

Canal is in soft weathered shale.

Station 108+00

Canal is in clayey sand with some boulders.

Station 114+00

Canal is in soft sandstone and shale.

Station 115+00

Canal is in clayey sand with some boulders.

Station 118+50

Canal is in soft sandstone and shale.

Station 123+00

Canal is in overburden of clay and boulders.

Station 125+50

Canal is in fairly hard, well cemented sandstone.

Station 128+00

Canal is in soft tan-colored shale.

Station 140+50

Canal is in sandy clay with boulders. This is part of an old pediment surface.

Station 142+00

Canal is one-half in shale and one-half in clay and boulders.

Station 152+00

Canal is in overburden of clayey sand with cobbles.

Station 160+00

Canal is in clayey sand with soft shale in the bottom.

Station 162+00

Canal is in clayey sand with large boulders (Maximum 15" in diameter).

Station 170+00

Canal is in topsoil of silty sand.

Station 171+00

Canal is in pediment of sandy clay and cobbles.

Station 176+00

Canal comes out in irrigated land with soil of windblown silty sand.

Station 220±

End of canal.

J. Neil Murdock

APPENDIX B
Ditch Loss Results for the Florida Canal from the Headgate at the Florida River to the Confluence

Appendix B-1

Ditch loss results for the Florida Canal from the headgate at the Florida River to the Confluence

[cfs, cubic feet per second; acre-ft/yr, acre-feet per year; --, negative losses indicate inconclusive result]

Site	Site Description	Date Time	Discharge Method	Discharge of Canal, cfs	Discharges of Diversions, cfs	Discharge Losses in Reach, cfs[a]	Reach Length, miles	Normalized Loss in Reach, cfs/mile/cfs	Loss in Reach, acre-ft/yr[b]
FC-0	Florida Canal at headgate	7/21/09 12:40	Current Meter AA	**53.1**					
FC-1	Florida Canal at CR234	7/21/09 9:00	Current Meter AA	**51.3**		**1.8**	0.48	0.070	536
FC-2	Florida Canal at Macho crossing	7/21/09 10:30	Current Meter AA	**50.8**		**0.5**	1.40	0.007	149
			Ditch Rider Reading		0.75				
			Ditch Rider Reading		0.5				
FC-3	Florida Canal at Horse Gulch	7/22/09 10:45	Current Meter AA	**46.0**	**1.25**	**4.1**	1.03	0.078	1,211
FC-4	Florida Canal at Busby property	7/22/09 12:30	Current Meter AA	**45.3**	**0.0**	**0.7**	2.28	0.007	205
			Ditch Rider Reading		0.1				
			Ditch Rider Reading		0.3				
FC-5	Florida Canal nr Squaw Apple Rd	7/22/2009 13:40	Current Meter AA	**43.7**	**0.4**	**1.3**	1.60	0.018	384
			Ditch Rider Reading		0.5				
			Ditch Rider Reading		4.0				
			Ditch Rider Reading		1.0				
			Ditch Rider Reading		6.5				
			Ditch Rider Reading		1.75				
			Ditch Rider Reading		0.5				
FC-6	Florida Canal at Confluence	7/22/2009 16:00	Flume	**30.0**	**14.3**	**-0.6**	2.60	-0.005	**--**

[a] Negative loss indicates discharge gain through reach due to irrigation return flows

[b] Annual losses calculated for 150 days of irrigation season per year at the canal flows occurring during the study

APPENDIX C
Ditch Loss Results for the Florida Farmers Ditch from the Headgate at the Florida River to the Confluence

Appendix C

Ditch loss results for the Florida Farmers Canal from the headgate at the Florida River to the Confluence

[cfs, cubic feet per second; acre-ft/yr, acre-feet per year; --, negative losses indicate inconclusive result]

Site	Description	Date Time	Discharge Method	Discharge of Canal, cfs	Discharges of Diversions, cfs	Discharge Losses in Reach, cfs[a]	Reach Length, miles	Normalized Loss in Reach, cfs/mile/cfs	Loss in Reach, acre-ft/yr[b]
FFC-0	Florida Farmers Ditch at headgate	7/14/2009 12:00	Flume	**157.0**					
			Ditch Rider Reading		0.25				
			Ditch Rider Reading		0.25				
FFC-1	Florida Farmers Ditch blw Payne Siphon	7/14/09 10:00	Tracer Dilution	**143.3**	**0.5**	**13.2**	1.52	0.055	3,932
			Ditch Rider Reading		0.75				
			Ditch Rider Reading		2.75				
FFC-2	Florida Farmers Ditch at CR 236	7/14/09 13:00	Tracer Dilution	**131.0**	**3.5**	**8.8**	1.23	0.050	2,607
			Ditch Rider Reading		9.25				
			Ditch Rider Reading		1				
FFC-3	Florida Farmers Canal, Flume at confluence	7/14/09 13:40	Flume	**124.0**	**10.25**	**-3.2**	0.95	-0.026	--

[a] Negative loss indicates discharge gain through reach due to irrigation return flows

[b] Annual losses calculated for 150 days of irrigation season per year at the canal flows occurring during the study

APPENDIX D
Ditch Loss Results for the Florida Canal South from the Confluence to Pastorius Lake

Appendix D

Ditch loss results for the Florida Canal South from the Confluence to Pastorius Lake

[cfs, cubic feet per second; acre-ft/yr, acre-feet per year]

Site	Site Description	Date	Method	Discharge of Canal, cfs	Discharges of Diversions, cfs	Discharge Losses in Reach, cfs[a]	Reach Length, miles	Normalized Loss in Reach, cfs/mile/cfs	Loss in Reach, acre-ft/yr[b]
FCS-1	Florida Canal South below Confluence	7/30/09 9:50	Tracer dilution	**163.0**					
			Ditch Rider Reading		0.32				
			Ditch Rider Reading		3.0				
			Ditch Rider Reading		0.75				
			Ditch Rider Reading		1.0				
			Ditch Rider Reading		55.0				
			Ditch Rider Reading		0.75				
FCS-2	Florida Canal South above CR 172	7/30/09 13:45	Tracer dilution	**101.7**	**60.82**	**0.52**	0.52	0.006	154
			Ditch Rider Reading		5.5				
			Ditch Rider Reading		0.5				
			Ditch Rider Reading		3.25				
FCS-3	Florida Canal South at Pastorius Lake	7/30/09 12:15	Tracer dilution	**87.9**	**9.3**	**4.51**	2.66	0.017	1,341

[a] Negative loss indicates discharge gain through reach due to irrigation return flows

[b] Annual losses calculated for 150 days of irrigation season per year at the canal flows occurring during the study

APPENDIX E
Ditch Loss Results for the Florida Farmers Ditch West from the Confluence to Pastorius Lake

Appendix E

Ditch loss results for the Florida Farmers West Canal from the Confluence to Pastorius Lake

[cfs, cubic feet per second; acre-ft/yr, acre-feet per year; --, negative losses indicate inconclusive result]

Site	Site Description	Date	Discharge Method	Discharge of Canal, cfs	Discharges of Diversions, cfs	Discharge Losses in Reach, cfs[a]	Reach Length, miles	Normalized Loss in Reach, cfs/mile/cfs	Loss in Reach, acre-ft/yr[b]
FFW-1	Florida Farmers West below Confluence	7/29/09 10:30	Current Meter AA	**36.0**					
			Ditch Rider Reading		0.5				
			Ditch Rider Reading		1.25				
			Ditch Rider Reading		0.4				
			Ditch Rider Reading		0.5				
			Ditch Rider Reading		0.65				
FFW-2	Florida Farmers West above US Hwy 160	7/29/09 15:30	Tracer dilution	**27.3**	**3.3**	**5.4**	2.47	0.061	1,602
			Ditch Rider Reading		1.25				
			Ditch Rider Reading		2.0				
			Ditch Rider Reading		2.0				
			Ditch Rider Reading		3.0				
FFW-3	Florida Farmers West below Grandview	7/29/09 13:40	Tracer dilution	**16.4**	**8.25**	**2.6**	1.59	0.059	767
			Ditch Rider Reading		1.0				
			Ditch Rider Reading		1.1				
			Ditch Rider Reading		1.75				
			Ditch Rider Reading		5.6				
			Ditch Rider Reading		2				
			Ditch Rider Reading		1				
			Ditch Rider Reading		3				
FFW-4	Florida Farmers West at Pastorius Lake	7/29/09 12:30	Ditch Rider Reading	**3.3**	**15.5**	**-2.3**	1.48	-0.096	--

[a] Negative loss indicates discharge gain through reach due to irrigation return flows

[b] Annual losses calculated for 150 days of irrigation season per year at the canal flows occurring during the study

Appendix F
Soil Descriptions from the Soil Conservation Service Soil Survey of La Plata County Area, Colorado

Soil Descriptions from the Soil Conservation Service Soil Survey of La Plata County Area, Colorado

Hesperus Loam, 3-12 percent slopes. This deep, well drained soil is on alluvial fans and valley bottoms. It formed in medium textured alluvium. Included in this unit are about 15 percent Herm loam and small areas of Nutrioso loam, Alamosa loam, and Shawna Variant loam. Permeability of the Hesperus Loam is moderate. Effective rooting depth is 60 inches or more. Available water capacity is high. Runoff is medium, and the hazard of erosion is slight. This unit is used mainly as rangeland , irrigated cropland, and homesites. The native vegetation on this unit is mainly bluegrass, western wheatgrass, Arizona fescue, mountain muhly, big sagebrush, mountain bromegrass, Gambel oak, serviceberry, and lupine. Significant ditch loss can be expected in areas where the canals cross over the Hesperus loam for a long distance. This was evident in the ditch loss measurements of the Florida Farmers Ditch, where the most significant loss (3932 AF/yr) occurred in Reach G, which crosses over this soil type (Figure 3).

Rock outcrop. This map unit is on cliffs, breaks, ridges, and mountainsides. It consists mainly of areas of exposed sandstone and shale. Included in this unit are small areas of soils that are shallow or very shallow over bedrock. The native vegetation is sparse, but may grow in the small areas of inclusions and in cracks and fissures of the rock outcrop. Significant ditch loss is not anticipated in areas where the canals cross over rock outcrops.

Tefton Loam. This deep, somewhat poorly drained soils is on floodplains and alluvial valley floors. It formed in mixed alluvium. Included in this unit are about 20 percent Pescar fine sandy loam, about 10 percent Alamosa loam, and small areas of soils that are similar to this Tefton loam but are better drained. Permeability of the Tefton loam is moderate or moderately slow. Effective rooting depth is 24 to 36 inches because of the presence of a high water table. Available water capacity is high. Runoff is slow, and the hazard of erosion is moderate. This soil has a fluctuating water table in most places that rises to within two to three feet of the surface during spring and summer. This soil is subject to flooding which mainly occurs during spring runoff or during the rainy season in the fall. The native vegetation on this unit is mainly tufted hairgrass, slender wheatgrass, redtop, Nebraska sedge, Baltic rush, cottonwood, bluejoint reedgrass, and willows. Due to the presence of a high water table associated with this soil coupled with a moderately slow permeability rate, significant ditch loss is not anticipated in this soil. The Tefton loam is encountered in Reach B, of the Florida Canal, on Figure 3, and this reach exhibited the lowest volume of loss (149 AF/yr) that was identified in the study.

Ustic Torrierthents-Ustollic Haplargids complex. This map unit is on terrace edges, mesa edges, and hillsides. This unit is 50 percent Ustic Torriorthents and 30 percent Ustollic Haplargids. The Ustollic Haplargids are in the less sloping areas. Included in this unit are about 15 percent soils that are underlain by bedrock at a depth of 40 inches or less and 5 percent shale and sandstone rock outcrop. Ustic Torriorthents are deep and somewhat excessively drained. These soils formed in outwash. No single profile of Ustic Torriorthents is typical, but one commonly observed in the survey area has a surface layer of gravelly or cobbly loam or fine sandy loam. The substratum is gravelly or very cobbly outwash. Permeability of these Ustic Torriorthents and Ustollic Haplargids varies depending on the texture of the parent material. Effective rooting depth is 40 inches or more. Available water capacity is low. Runoff is rapid, and the hazard of erosion is high. The native vegetation on this unit is mainly western wheatgrass, Indian rice grass, needle and thread, blue grama, mutton grass, Fendler threeawn, june grass, big sagebrush, rabbit brush, pinyon, Rocky Mountain juniper, ponderosa pine, mountain mahogany, serviceberry, snowberry, and Gambel oak. Steepness of slope limits access by livestock and promotes overgrazing of the less sloping areas. Significant ditch losses have been measured in ditch reaches that cross over the Ustic Torrierthents-Ustollic Haplargids complex. Payne Canyon contains soils of the Ustic Torrierthents-Ustollic Haplargids complex and this is an area that has been identified by the ditch riders of the FWCD as an area of ditch loss. This soil is mostly encountered in reaches E and G on Figure 3.

Archuleta-Sanchez Complex, 12 to 65 percent slopes. This map unit is on hills, ridges, and mountainsides. This unit is 45 percent Archuleta loam and 30 percent Sanchez very stony sandy clay loam. Included in this unit are about 10 percent Corta Loam, 5 percent Hesperus loam, and 10 percent Rock outcrop, Bodot clay, Zyme clay loam, and Arboles Clay. The Archuleta soil is shallow and well drained. It formed in residuum derived from interbedded sandstone and shale. Typically, the surface is covered with a mat of organic material about 1 inch thick. The surface layer is light brownish gray loam about 4 inches thick. Below this is pale brown clay loam about

8 inches thick over interbedded sandstone and shale. Depth to bedrock ranges from 10 to 20 inches. In some places the surface layer is sandy loam. Permeability of this Archuleta soil is moderate. Effective rooting depth is 10 to 20 inches because of the presence of soft bedrock. Available water capacity is low. Runoff is rapid, and the hazard of erosion is moderate. The Sanchez soil is shallow and well drained. It formed in residuum derived from interbedded sandstone and shale. Typically, the surface layer is pale brown very stony sandy clay loam about 5 inches thick. The subsoil is light brownish gray very stony clay loam about 6 inches thick. The substratum is light brownish gray stony sandy clay loam. Sandstone is at a depth of 15 inches. Depth to bedrock ranges from 11 to 20 inches. In some places the surface layer is very stony sandy loam. Permeability of this Sanchez soil is moderately slow. Effective rooting depth is 11 to 20 inches because of the presence of hard bedrock. Available water capacity is very low. Runoff is rapid, and the hazard of erosion is moderate. The native vegetation on this unit is ponderosa pine, Gambel oak, bitterbush, fringed sagebrush, mountainmahogany, serviceberry, snowberry, Oregon-grape, Arizona fescue, mountain brome, bluegrass, elk sedge, and a few pinyon and Rocky Mountain juniper. The Florida Canal passes over the Archuleta-Sanchez complex for a relatively short distance on Reach B shown on Figure 3. Moderate ditch loss could result from the reach that crosses over the Archuleta-Sanchez complex based on its range of permeability.

Vosburg Fine Sandy Loam. This deep well drained soil is in swales and on foot slopes of uplands. It formed in medium textured alluvium derived from sandstone and shale. Typically, the surface layer is dark grayish brown fine sandy loam about 15 inches thick. The upper part of the subsoil is dark grayish brown clay loam about 3 inches thick, the next part is dark grayish brown sandy clay loam about 13 inches thick, and the lower part is brown sandy clay loam about 19 inches thick. The substratum is brown sandy clay loam that extends to a depth of 60 inches or more. Included in this unit are 15 percent Umbarg loam and small areas of soils that do not have a thick, dark colored surface layer. Permeability of this Vosburg soil is moderate. Effective rooting depth is 60 inches or more. Available water capacity is high and runoff is medium. The native vegetation on this unit is mainly Indian ricegrass, junegrass, western wheatgrass, blue grama, and big sagebrush. This soil is encountered on the Florida Canal where the canal crosses Horse Gulch on Reach D (Figure 3), Significant losses resulting from this soil could be expected due to its high permeability.

Shawa Varient loam, 5 to 20 percent slopes. This deep, well drained soil is on mountainsides. It formed in alluvial and colluvial material. Typically, the surface layer is grayish brown loam about 23 inches thick. The next layer is grayish brown loam about 17 inches thick. The underlying material is light brownish gray cobbly loam that extends to a depth of 60 inches or more. Included in this unit are about 15 percent Nutrioso loam and small areas of a soil that has more coarse fragments between depths of 10 and 40 inches than is typical of this Shawa Variant soil. Permeability of this Shawa Variant soil is moderate. Effective rooting depth is 60 inches or more. Available water capacity is high. Runoff is medium, and the hazard of erosion is slight. The native vegetation on this unit is mainly ponderosa pine, junegrass, mountain muhly, mountain brome, Arizona fescue, bluegrass, serviceberry, and Gambel oak. The Florida Canal encounters this soil as it serpentines between Horse Gulch and Payne Canyon on Reach D of Figure 3. Moderate losses could be expected from this soil type due to its permeability.

Falfa clay loam, 1 to 3 percent slopes. This deep, well-drained soil is located on mesa tops, and is formed in calcareous loess. Typically, the surface layer is reddish brown clay loam about 9 inches thick. The upper part of the subsoil is reddish brown clay loam about 5 inches thick, the next part is reddish brown clay about 20 inches thick, and the lower part is reddish brown clay loam about 23 inches thick. The substratum to a depth of 60 inches or more is yellowish red clay loam. Included in this unit are about 10 percent Corta loam, 5 percent soils that are similar to this Falfa soil but have a dark-colored surface layer, and small areas of Witt loam and Simpatico loam. Permeability of this Falfa soil is slow. Effective rooting depth is 60 inches or more. Available water capacity is high. Runoff is medium, and the hazard of erosion is moderate. The native vegetation is mainly western wheatgrass, muttongrass, junegrass, Indian ricegrass, big sagebrush, Gambel oak, serviceberry, Rocky Mountain juniper, and pinyon. Low soil strength and high shrink-swell potential are the main limitations for homesite and urban development. The foundations of buildings should be designed to compensate for the high shrink-swell potential of the soil. Roads should be designed to overcome the limitations of low soil strength and high shrink-swell potential. The slow permeability should be considered when planning septic tank absorption fields. Significant ditch losses are not anticipated in sections of ditch that cross over the Falfa clay loam. Ditch loss measurements of ditch reaches that cross the Falfa clay loam were among the lowest losses in the study. These reaches include F, I, J, and N (Figure 3).

Falfa clay loam, 3 to 8 percent slopes. This deep, well-drained soil is on mesa tops, and is formed in calcareous loess. Typically, the surface layer is reddish brown clay loam about 9 inches thick. The upper part of the subsoil is reddish brown clay loam about 5 inches thick, the next part is reddish brown clay about 20 inches thick, and the lower part is reddish brown clay loam about 23 inches thick. The substratum is yellowish red clay loam that extends to a depth of 60 inches or more. Included in this unit are about 10 percent Corta loam, 5 percent soils that are similar to this Falfa soil but have a dark-colored surface layer, and small areas of Witt loam and Simpatico loam. Permeability of this Falfa soil is slow. Effective rooting depth is 60 inches or more. Available water capacity is high. Runoff is medium, and the hazard of erosion is moderate. Realignment of ditches and irrigation structures is needed in some areas to achieve a more uniform distribution of irrigation water. Diversions and grassed waterways may be needed to reduce gully erosion. Low soil strength and high shrink-swell potential are the main limitations for homesite and urban development. The foundations of buildings should be designed to compensate for the high shrink-swell potential of the soil. Roads should be designed to overcome the limitations of low soil strength and high shrink-swell potential. The slow permeability should be considered when planning septic tank absorption fields. Significant ditch losses are not anticipated in sections of ditch that cross over the Falfa clay loam. Ditch loss measurements of ditch reaches that cross the Falfa clay loam were among the lowest losses in the study. These reaches include F, I, J, and N (Figure 3).

Simpatico loam. This deep, well-drained soil is in drainage ways on mesa tops. It formed in alluvium derived from nearby loess deposits. Slope is 1 to 3 percent. Typically, the upper part of the surface layer is grayish brown loam about 6 inches thick, and the lower part is grayish brown silt loam about 6 inches thick. The upper part of the subsoil is brown silty clay loam about 22 inches thick, and the lower part is reddish brown silty clay loam about 11 inches thick. The substratum is light brown cobbly loam that extends to a depth of 60 inches or more. Included in this unit, in areas east of the Animas River, are about 15 percent Falfa clay loam and about 15 percent soils that are underlain by gravel and cobbles at a depth of 40 inches. Permeability of this Simpatico soil is moderately slow. Effective rooting depth is 60 inches or more. Available water capacity is high. Runoff is slow, and the hazard of erosion is slight. The soil is subject to flooding during periods of heavy rainfall and snowmelt. The hazard of flooding is the main limitation for homesite and urban development. Use of diversions, drainage, and other protective measures is necessary for homesite and urban development. Low soil strength and moderate shrink-swell potential are also limitations. The foundations of buildings should be designed to compensate for the shrink-swell potential of the soil. Roads should be designed to overcome the limitation of low soil strength. The hazard of flooding and the moderately slow permeability should be considered when designing septic tank absorption fields or sewage lagoons.Moderate losses could be expected in reaches that cross the Simpatico loam. Reach L crosses through multiple soils, but the Simpatico soil is likely the soil causing losses within this reach, because when compared to the adjacent soils, the Simpatico loam is generally more permeable than the adjacent soils (Figure 3).

Arboles Clay, 3 to 12 percent slopes. This deep, well drained soil is on side slopes and in upland valleys. It formed in fine textured alluvium derived from shale. Typically, the surface layer is brown clay about 6 inches thick. The subsoil is brown clay about 24 inches thick. The substratum is brown and reddish yellow clay loam that extends to a depth of 60 inches or more. In most undisturbed areas the surface layer is silty clay loam. included in this unit are about 15 percent Bodot clay and small areas of Bayfield silty clay loam, Sili clay loam, and Zyme clay loam. Permeability of this Arboles soil is slow. Effective rooting depth is 60 inches or more. Available water capacity is high. Runoff is medium, and the hazard of erosion is moderate. When the soil is dry, it has deep, wide cracks that extend to the surface. The rangeland vegetation on this unit is mainly Indian ricegrass, junegrass, western wheatgrass, big sagebrush, Gambel oak, squaw-apple, bitterbrush, pinyon, and Rocky Mountain juniper. Because the permeability of the Arboles Clay is slow, significant ditch loss is not anticipated from this soil. This soil is encountered by the Florida Farmers West Ditch on the top of Florida Mesa, on Reach L shown on Figure 3.

Pescar fine sandy loam. This deep, somewhat poorly drained soil is on floodplains, low terraces, and alluvial valley floors. It formed in stratified calcareous alluvium. Slope is 0 to 2 percent. Typically, the surface layer is light brownish gray fine sandy loam about 8 inches thick. The upper 12 inches of the underlying material is light brownish gray fine sandy loam that is stratified with loam and loamy fine sand, and the lower part to a depth of 60 inches or more is light brownish gray very gravelly sand. Included in this unit are about 15 percent Teflon loam, small areas of soils that are wetter than this Pescar soil, and small areas of soils that are drier than this Pescar soil. Permeability of this Pescar soil is moderately rapid. Effective rooting depth is 18 to 30 inches because of the presence of a high water table. Available water capacity is low. Runoff is very slow and the hazard of erosion is slight. This soil has a fluctuating water table that is between depths of 18 and 30 inches in spring and summer. The soil is subject to frequent flooding from April through September. This unit is used mainly for irrigated pasture and hay and as rangeland. Drainage ditches may be needed to control the water table. The native vegetation on this unit is mainly sedges, rushes, tufted hairgrass, slender wheatgrass, yarrow, iris, willows, and cottonwood. Significant ditch losses could be expected in reaches that cross over this soil type. A short segment of the Florida Canal crosses this soil type on Reach K (Figure 3).

Zyme clay loam, 3 to 25 percent slopes. This shallow, well drained soil is on ridges and hills. It formed in residuum derived from shale. Typically, the surface layer is grayish brown clay loam about 4 inches thick. The underlying material is grayish brown clay loam over a soft shale at a depth of 10 inches. Depth to bedrock ranges from 6 to 20 inches. Included in this unit are about 15 percent Bodot clay, 10 percent Arboles silty clay loam, and small areas of Dulce sandy loam, Travessilla sandy loam, and Rock outcrop. Permeability of this Zyme soil is slow. Effective rooting depth is only 6 to 20 inches because of the presence of soft bedrock. Available water capacity is low. Runoff is rapid, and the hazard of erosion is high. The native vegetation in most areas consists of Indian ricegrass, western wheatgrass, needleandthread, blue grama, pinyon, Rocky Mountain juniper, mountainmahogany, Gambel oak, bitterbrush, serviceberry, and big sagebrush. The Zyme clay loam is encountered by the Florida Farmers West Ditch on top of the Florida Mesa. Significant ditch losses are not expected from ditch segments that cross through this soil type.

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