ZUNI RIVER BASIN

DETERMINATION OF WATER USES
FOR
SUBFILE ZRB-2-0038

In the matter of
United States et al. v. A&R Productions et al.
Case # 01cv00072 MV/WPL

Prepared for:
United States Department of Justice

Rule 26(a)(2) Disclosure

Prepared by:

Natural Resources Consulting Engineers, Inc.
131 Lincoln Avenue, Suite 300
Fort Collins, Colorado 80524
(970) 224-1851 / Fax (970) 224-1885

July 7, 2016

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1 Introduction

1.1 Background

This report is prepared in connection the water right claims associated with the Zuni River Basin Adjudication subfile action ZRB-2-0038 (Craig and Regina Fredrickson, Defendants) in the matter of United States, et al. v. A&R Productions, et al., Case No. 01cv00072-MV/WPL. Mr. Craig Fredrickson has provided three documents titled “Expert Report of Craig L. Fredrickson” in each of which he provides calculations and opinions as to the livestock watering use associated with well 10A-5-W06 (Fredrickson, 2016a; Fredrickson, 2016b; Fredrickson, 2016c). This report generally addresses the most recent iteration of Mr. Fredrickson’s report (Fredrickson, 2016c). Any references to Mr. Fredrickson’s earlier reports are cited as such where necessary.

Natural Resources Consulting Engineers, Inc. (NRCE) is the contractor retained by the United States Department of Justice (Plaintiffs) to conduct the hydrographic survey of the Zuni River Basin and estimate historical water uses throughout the basin. NRCE (est. 1989) is a civil, environmental, and water resources engineering consulting firm that specializes in agricultural engineering, hydrology, and providing expert support for water right disputes. Based upon the procedures described in the *Hydrographic Survey Report for Subareas 9 & 10* (NRCE, 2005) and information collected by NRCE engineers during consultations with the Fredricksons, the water right assigned to well 10A-5-W06 (a/k/a “Rincon Hondo Windmill”) was computed to be 3.724 acre-feet per annum for livestock and domestic purposes. The Defendants’ have claimed 3.779 acre-feet per annum for livestock use as described in Mr. Fredrickson’s report. The total quantity sought by the Defendants’ is 4.479 acre-feet per annum which includes an additional 0.7 acre-feet per annum for domestic usage (Fredrickson, 2016c). This report reviews some of the assumptions, analysis, and conclusions stated in Mr. Fredrickson’s report.

1.2 Statement of Qualifications

This report is prepared by Scott Turnbull, who is an Associate Engineer with Natural Resources Consulting Engineers, Inc. in Fort Collins, Colorado. He holds a Bachelor of Science in Civil Engineering and is a licensed Professional Engineer in the state of Colorado (No. 47227). Mr. Turnbull has over eight years of experience in water resources and agricultural engineering. His engineering experience includes water system design, hydraulic analysis, estimation of crop irrigation and diversion requirements, estimation of livestock water use, water resources planning, field work for surveying and documentation of water features and associated uses, cost estimation, and providing analysis for domestic, irrigation, livestock, and municipal water use studies. Mr. Turnbull's resume is in Appendix A.

1.3 Disclaimer

Pursuant to Rule 26 of the Federal Rules of Civil Procedure, the United States has compensated NRCE $21,400 for the preparation of this report and if Mr. Turnbull is required to testify concerning this report the United States will be charged an hourly rate of $130 plus any expenses.

2 Carrying Capacity

The carrying capacity of a given area is based upon the land's capability to consistently provide sufficient, palatable, forage for animal consumption without additional supplemental feeding of livestock. In his report, Mr. Fredrickson presents an analysis of the carrying capacity of rangeland in the vicinity of the "Rincon Hondo Windmill" (10A-5-W06) and "High Lonesome well" (no hydrographic survey label) in an attempt to determine or confirm the number of animals having been historically served by the well. Mr. Fredrickson conducted an analysis that includes estimation of the available forage as developed through soil surveys and guidelines to estimate the theoretical carrying capacity associated with lands near each well. As discussed below, Mr. Fredrickson relies upon unsupported assumptions which overestimate the theoretical carrying capacity and, furthermore, do not reflect the historical cattle stocking practices as described by the former land owner and ranch operator, Mr. Tom Cox, described during his May 18, 2016 deposition (Cox Dep., 2016).

2.1 Place of Use

The Fredricksons own all of section 19 (640 acres) in T5N R18W (Cibola County, 2009) in which well 10A-5-W06 is located. Areas outside of the property are components of other subfile actions. In his report, Mr. Fredrickson assumes well 10A-5-W06 to have historically served all land within a 2-mile radius of the well (Fredrickson, 2016c, p. 24). This approach appears to be taken from range usage guidelines which advise land further than 2 miles from any water source will not be utilized by grazing animals (Holechek, 1988). Mr. Fredrickson does not provide any additional basis for this distance and further proposes that in a favorable year, there would be sufficient forage to support the entire cattle herd in this 2-mile radius of 10A-5-W06. Additionally, the grazing capacity of a pasture can be greatly affected by pasture shape (e.g. a circle vs. a long canyon) even if pasture area and forage quantity are similar (Valentine, 1947). Mr. Fredrickson's approach is theoretical and not based upon any documented historical use of the well in question.

Furthermore, Mr. Fredrickson's assumption is conflicting to the ranch operation described by Mr. Cox that the cattle have watered at up to six sources throughout the year and the extent that they may have grazed (Cox Dep. 2016, p. 32). Particularly with respect to the summer range described by Mr. Cox, a portion of this 2-mile radius around well 10A-5-W06 used in Mr. Fredrickson's analysis was not grazed because Mr. Cox described this well as existing at the edge of the summer range due to the manner in which it is fenced-off (Cox Dep., 2016, p. 37-38).

2.2 Alternative Watering Sources

Documents provided by the Fredricksons provide limited description of the historic livestock use of well 10A-5-W06 by the immediate past owner and ranch operator. According to the 2008 response signed by Mr. Tom Cox, well 10A-5-W06 has historically served 150 cattle for 8 months of the year (Cox, 2008). While Mr. Cox's letter states an animal count and period of use, it does not include any detail or discussion regarding specific cattle management practices or how the well was historically used to water these cattle.

Mr. Cox was deposed by parties to this subfile action on May 18, 2016. Mr. Cox described with specificity his ranching practices associated with well 10A-5-W06 and throughout the Rincon Hondo area. The total cattle herd size in the Rincon Hondo area was about 150 to 200 head (Cox Dep., 2016, p. 32). When in the Rincon Hondo canyon, Mr. Cox stated that about 40% of the herd water at well 10A-5-W06 (Rincon-Hondo well) during December to July with the remainder of the herd watering at the Amado and Rincon Camp wells during this period (Cox Dep., 2016, pp. 33-37). During the July through November period, the herd of 150 to 200 cattle was free to roam over a rangeland consisting of four watering sources: Perry well, High lonesome well, Zuni spring, and well 10A-5-W06 (Cox Dep., 2016, p. 42). As mentioned above, the grazing area around this well was at the edge of the summer range described by Mr. Cox. At no point during the operation described by the former owner and operator, Mr. Cox, was well 10A-5-W06 the only watering source for cattle herd. Furthermore, Mr. Cox did not make any suggestion that any one watering source was used by the cattle more than the other sources. Without any further information regarding the dependence of the cattle on any single source, it is practical to conclude that they were used equally. These wells have been located based upon Mr. Cox's descriptions and are shown in Figure 1. Note that NRCE engineers have not visited any features outside of the adjudication boundary.

In his report, Mr. Fredrickson discounts each of the alternative watering sources and claims that his well, 10A-5-W06, is where the cattle drank under favorable forage conditions (Fredrickson, 2016c, p. 40). Regarding the Perry Canyon and Amado wells, Mr. Fredickson states that they are undependable sources because they fail NRCS design requirements due to lack of adequate storage (Fredrickson, 2016c, p. 20). Failure of a watering facility to meet any specific set of design criteria or recommendations does not mean the cattle will not utilize the watering source. In fact, the NRCS states in that same report that "Animals will tend to learn when water is available. Therefore, as long as the daily requirement is supplied, the animals will obtain what they need" (NRCS, 2010). Furthermore, Mr. Cox stated that both the Perry and Amado wells are shallow and pumped easy without a pump jack (Cox Dep., 2016, pp. 52-53). Regarding the Perry Well, Mr. Cox stated that the herd relied upon water from this well despite the fact that it contained gypsum (Cox Dep., p. 52-53). Regarding the High Lonesome well, Mr. Fredrickson states that although it has similar infrastructure to 10A-5-W06, cattle would not utilize this well because the hypothetical favorable forage amount located within 2-miles of 10A-5-W06 would be sufficient to sustain the cattle herd. Again, this assumption directly contradicts the description of the ranch's operation by Mr. Cox (Cox Dep., pp. 41-42). Particularly, as Mr. Cox describes, well 10A-5-W06 exists at the edge of the summer range (Cox Dep., 2016c, p. 38).

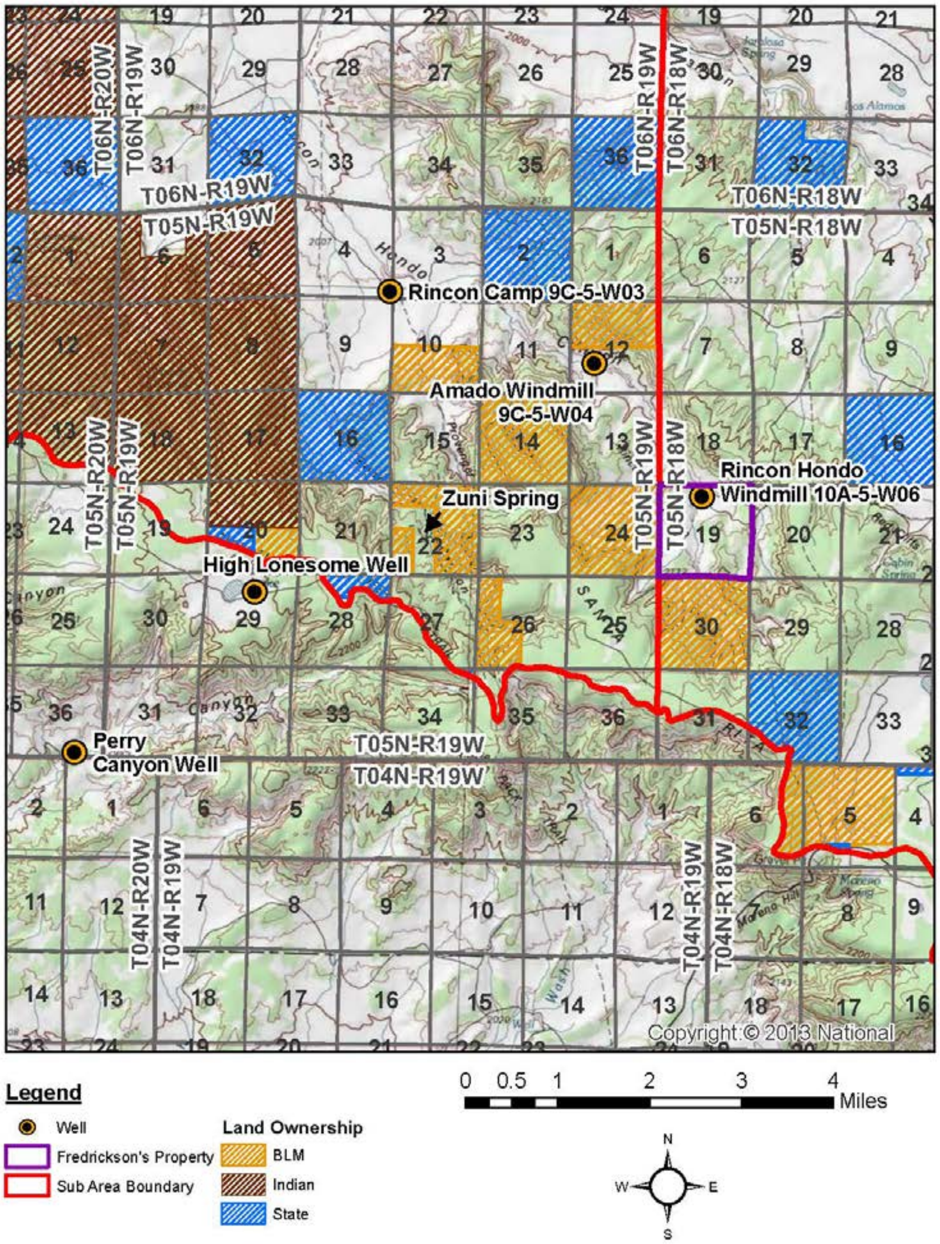

Figure 1 - Locations of Wells Serving the Cox Ranch at Rincon Hondo

2.3 Average vs. Favorable Year Forage Production

The NRCS soil surveys present forage production in pounds per acre for three conditions: favorable year, unfavorable year, and average year. A normal year of forage production represents climate conditions (precipitation and temperatures) that are about average. A favorable year of forage production represents conditions that are substantially better than average. This forage production quantity presented by NRCS and included in Mr. Fredrickson's analysis includes all vegetation, whether or not it is palatable to grazing animals. This is accounted for by selecting an appropriate utilization rate as discussed in the next section.

In Mr. Fredrickson's April 29, 2016 report he elects to apply the normal year forage production because "it is reasonable for a rancher to plan on average conditions and adjust cattle stocking rate and/or grazing period as climatic or market conditions dictate" (Fredrickson, 2016b, p. 19). In his June 27, 2016 report, Mr. Fredrickson elects to apply the favorable year forage production because it "represents the upper limit carrying capacity of the pasture" and is "justified based upon precipitation over the years 1983 to 2000" when Mr. Cox worked the ranch (Fredrickson, 2016c, p. 27). The PRISM Climate Group develops gridded climate data sets throughout the United States covering the period 1895 to the present day (PRISM, 2016). While it does appear that there was increase in precipitation during the early 1980s, perhaps leading to better forage conditions, the overall period of record corresponding to the well and cattle operation from about 1950 to 2000 shows typical precipitation with expected annual variability (see Figure 2).

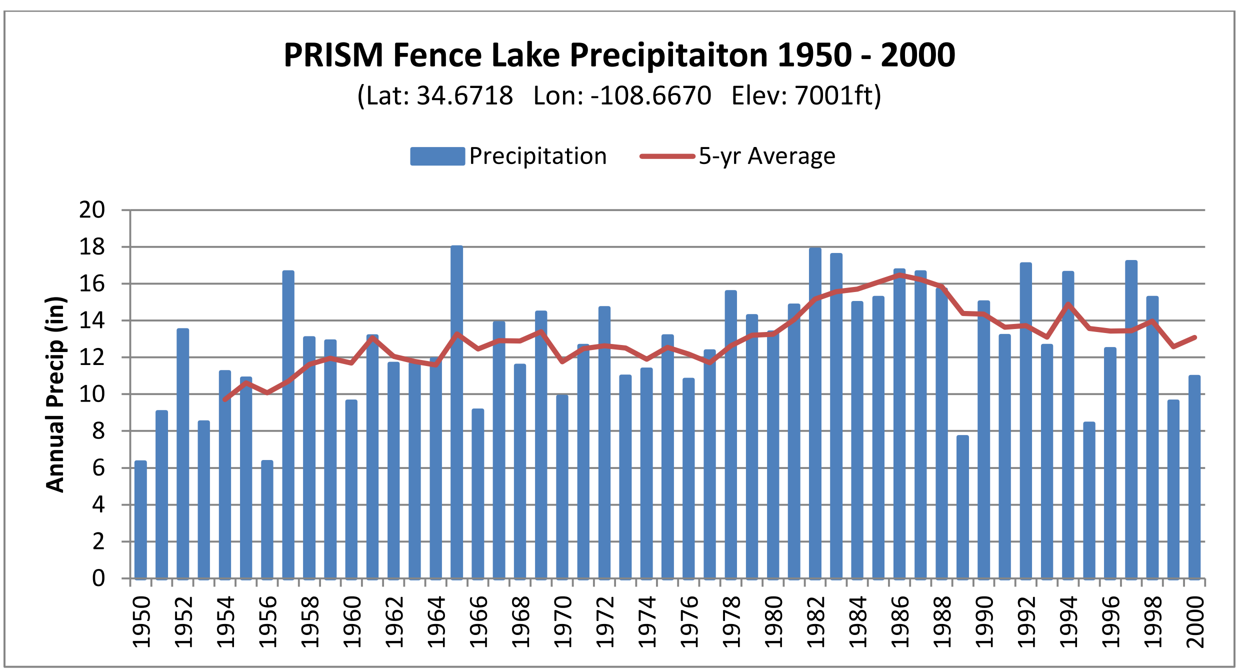

Figure 2 – Annual Precipitation at Fence Lake (PRISM, 2016)

2.4 Forage Utilization Rate

In his report, Mr. Fredrickson selects and applies a forage utilization rate of 45% to determine his theoretical grazing capacity. Although Mr. Fredrickson cites to Holechek (1988), he does not describe how he decided upon this specific utilization rate given the wide range of studies and utilization rates presented by Holechek (Fredrickson, 2016c, p. 28).

Selecting a proper forage utilization rate to estimate carrying capacity of a rangeland will ensure that the land is protected from overgrazing and remains productive from year-to-year. According to the forage utilization guidelines compiled from various studies in Holechek (1988), the semi-arid grass and shrubland range types common to western New Mexico correspond to a rangeland utilization of 30-40% under moderate grazing management conditions.[1] These studies cited in Holechek supporting utilization rates for 30-40% were conducted in New Mexico, Arizona, and Utah. The utilization rates of 40-50% cited in Holechek reflect studies conducted in Colorado, Nebraska, and Texas. Thus, Mr. Fredrickson's selected utilization rate does not appear to correspond to the type of rangeland found in the Zuni River Basin in western New Mexico.

In fact, some experts advocate for an even more restrictive forage utilization rate than the 30% to 40% reported in Holechek (1988). Galt et al. (2000) and Hurd et al. (2007) present a utilization rate of 25% for western rangelands when computing theoretical carrying capacities. The authors of Galt et al. (2000) state that "[a 25% harvest coefficient] allows both forage species and livestock to maximize their productivity, allows for error in forage production estimates, greatly reduces problems from buying and selling livestock, reduces the risk of financial ruin during drought years, and promotes multiple use values." A utilization rate of 25%, compared to Mr. Fredrickson's selected rate of 45%, would significantly reduce the theoretical carrying capacity of the land near well 10A-5-W06 and, as a result, show that the cattle would be expected to seek out forage elsewhere.

[1] Holechek (1988) recommends applying the lower utilization level from the guidelines when ranges are grazed during active growth. This would apply to Mr. Fredrickson's analysis where he assumes cattle are grazing during the year long period within 2-miles of well 10A-5-W06 (Fredrickson, 2016c, p. 40).

3 Animal Water Intake

Water intake of cattle is related to dry matter intake (DMI) and air temperature. An increase in DMI and/or an increase in air temperature results in higher water intake by the animal (Winchester and Morris, 1956). The hydrographic survey performed by NRCE applied average annual daily values reported by the New Mexico Office of the State Engineer of 10 gallons per beef cow per day (Wilson and Lucero, 1997). Mr. Fredrickson takes issue with the estimates made during the hydrographic survey which have been applied throughout the Zuni River Basin adjudication. In his report, Mr. Fredrickson presents an alternative theoretical analysis considering watering requirements for cattle given in NRC (2000) which are based upon the work of Winchester and Morris (1956). The following sections review Mr. Fredrickson's assertions considering scenarios of both water use by mature beef cattle and water use by lactating cows and their calves.

In NRC (2000), the water intake rates for cattle are tabulated based upon air temperature with no indication given as to whether the temperatures correspond to daily maximum or mean temperatures. These values in NRC are taken from Winchester and Morris (1956) which describes the temperatures as the ambient temperature. The water intake rates for cattle presented in Winchester and Morris are primarily based on data measured when cattle are in constant temperature conditions (Ragsdale et al., 1951). These conditions are different from the "ambient daytime temperature" calculated by Mr. Fredrickson (Fredrickson, 2016c, p. 42). Winchester and Morris noted that cattle in outdoor conditions with temperatures ranging from 58° to 122°F, with a mean of 90°F, drank about the same amount as the cattle in constant 90°F chambers. Thus, the authors pooled mean temperature data with data measured under constant temperature conditions. Winchester and Morris further compare their results with information from other sources by using mean temperatures. In an effort to estimate forage intake of cattle by measuring water intake, Hyder (1970) elected to use mean air temperatures derived from daily minimum and maximum values when applying water intake rates from Winchester and Morris. Thus, the appropriate temperature to use in analysis when applying NRC or Winchester and Morris intake rates for cattle seems to be mean temperatures, not the "ambient daytime temperature" developed by Mr. Fredrickson.

3.1 Water Intake Requirements of a Mature Beef Cow

Throughout consultations with land owners and ranchers, and from observations made during the hydrographic survey, NRCE engineers have found the primary use of livestock water in the Zuni River Basin is to water beef cattle. A “beef cattle operation” refers to an operation which consists of grazing cattle to facilitate animal weight gain so the animals can then be sold at a profit to the rancher. NRCE consulted technical publications from the New Mexico Office of the State Engineer to determine average daily water use of beef cows (Wilson and Lucero, 1997). In his report, Mr. Fredrickson presents an alternative to the values from Wilson and Lucero (1997) using water intake values published by the National Research Council (NRC, 2000) from a study by Winchester and Morris (1956). Mr. Fredrickson describes this source as “a more comprehensive study of this topic” (Fredrickson, 2016, p. 41). With a known air temperature, the water intake values presented in Winchester and Morris can be compared with Wilson and Lucero. As explained below, the water intake values presented in both publications compare favorably.

The average monthly water intake (in gallons per capita per day, gpcd) of a 1,000 pound beef cow is shown in Table 1 with monthly average water intake interpolated from the tables in Winchester and Morris (1956). Monthly average temperatures are computed from monthly average high and low temperatures recorded at the nearby Fence Lake weather station for years 1933-2010 (WRCC, 2016a). The estimated annual average water intake for beef cattle is 8.0 gpcd (not including any water provided in feed which would go towards satisfying drinking requirements). This value is less, but compares favorably with, the 10 gpcd for beef cattle stated by Wilson and Lucero (1997).

Table 1 - Approximate Daily Intake of a 1,000-lb Beef Cow at Fence Lake, NM

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Mean Monthly Temp (°F)	30.2	34.1	39.7	46.3	55.0	63.9	69.4	66.9	60.6	49.9	38.6	31.0	48.8
Water Intake (gpcd)	7.0	7.0	7.0	7.4	8.2	9.3	10.1	9.7	8.8	7.6	7.0	7.0	8.0

In addition to the Winchester and Morris (1956) approach, NRC (2000) presents a formula from Hicks et al. (1988) for computing water intake based upon maximum temperature (MT °F), dry matter intake (DMI kg/day), precipitation (PP cm/day), and dietary salt (DS %): Water intake (L/day) = -18.67 + 0.3937MT + 2.432DMI – 3.870PP – 4.437DS (NRC, 2000). At an average annual maximum temperature of 65.8°F at the Fence Lake weather station (WRCC, 2016a), DMI of 20 lbs/day (9.1 kg/day), and disregarding reductions for precipitation or dietary salt, the total water intake predicted by the Hicks et al. equation is 29.3 L/day (7.8 gallons per day). This is similar to the 8.0 gpcd computed using intake rates from NRC or Winchester and Morris as previously shown in Table 1.

With all of these sources considered, it appears that the 10 gpcd applied by NRCE is a reasonable estimate to compute average annual water requirements of a typical beef cow in the Zuni River Basin.

3.2 Water Intake Requirements of a Cow-Calf Pair

The central argument in Mr. Fredrickson's report is that he believes the historical use of water at well 10A-5-W06 has related to a cattle breeding operation based upon his past conversations with both Mr. Tim Cox and Mr. Tom Cox (Fredrickson, 2016c, p. 9). This was confirmed by Mr. Cox during his deposition (Cox Dep., 2016). In contrast to a "beef cattle operation", the goal of a "cow-calf operation" is to breed calves for sale which are then sold to other cattle operators. Lactating beef cows with nursing calves will consume more water than non-lactating cattle (NRC, 2000). Mr. Fredrickson computes that the average daily water intake is 19.66 gallons per day per animal unit for the cow-calf operation.

Winchester and Morris (1956) provides values for daily water intake as a function of air temperature and daily DMI. In his forage analysis, Mr. Fredrickons elects to apply a definition of animal unit of 26 pounds of dried forage intake per day for a 1,000 lactating cow with a calf from the NRCS Range and Pasture Handbook (NRCS, 1997). Holechek and Piper (1992) acknowledge that the average 2% DMI requirements for cows presented in Holechek (1988) do not include additional forage intake by calves. Since a cow-calf pair, as an "animal unit", is specifically defined as it relates to daily DMI consumption, and Winchester and Morris provide water intake rates as a function of daily DMI consumption, the total water intake per AU can be directly computed. Furthermore, since this definition considers the cow-calf pair as a single unit based on forage consumption of the pair, the water requirements of the cow and calf do not need to be computed separately. A cow-calf pair on average consumes 2.58% of the pair's body weight (Meyer et. al, 2012). Assuming a lactating cow (1,000 lbs.) and its calf (200 lbs. average through the season), the total DMI for the pair is about 31 pounds of dry-matter per day. This is similar to the 30 pounds of air-dry forage recommendation for an animal unit as defined by NRCS (1997).

3.2.1 <u>Description of Cattle Operation at well 10A-5-W06</u>

According to the May 18, 2016 deposition of Mr. Tom Cox, the historic cattle operation and the associated cattle water use at well 10A-5-W06 can be described as follows:

- Operation was for cows breeding calves with a 90% calf crop (Cox Dep., p. 24).
- 150 to 200 cattle (Cox Dep., p. 32)
- 1 bull for every 10 cows (Cox Dep., p. 24)
- Six watering sources in the Rincon area: Rincon Camp well, Amado well, Rincon-Hondo well, Zuni Spring, Perry Canyon well, and High Lonesome well (Cox Dep., pp. 31-32).
- 40% of the herd would water at the Rincon Hondo well (Cox Dep., p. 36) during the winter – December to July (Cox Dep., p. 37).
- The herd would be moved to the higher elevations for the summer, starting in July (Cox Dep., p. 37).
- The entire herd, including cows, calves, and bulls, would water at the Perry well, High Lonesome well, and Rincon Hondo well during the summer, July – November, before cattle were removed and calves sold off (Cox Dep., pp. 37-39).

In summary, Mr. Cox described an operation of 150 to 200 cattle of which 40% would water at well 10A-5-W06 during the "winter" period as pregnant cows or as cow-calf pairs. The cow-calf pairs would then be moved, along with bulls, to an area served by three wells and a spring during the "summer" period. Each of these periods is associated with different water intake requirements based upon cattle type and temperature. For simplicity, although the spring calves are typically born March through May (Cox Dep., p. 20), the middle month of April is assumed as the month calves are born.

3.2.2 Water Requirements – Winter Period

The winter periods, as described by Mr. Cox, consisted of pregnant cows moving to the Rincon Hondo in December and remain there through spring birthing until the herd is moved in July. Thus, water requirements for two separate cattle classes need to be considered: pregnant cows and lactating cows with calves. Wintering pregnant cows consume 19.8 pounds of dry matter (DM) per day (Winchester and Morris, 1956). The DMI of cow-calf pairs is estimated as 31 pounds per day as previously discussed. Air temperatures are available at the nearby Fence Lake weather station (WRCC, 2016a). Applying the water intake rates from Winchester and Morris corresponding to the monthly mean temperature and cattle DMI, the average water intake during this period is computed to be 10.8 gpcd as shown in Table 2. This includes additional water intake by lactating cows to support milk production at a rate of 0.87 pounds of water per pound of milk produced (Winchester and Morris, 1956). Estimated adjustments due to moisture contained in growing pasture vegetation would reduce this total intake requirement. Adjustments to do forage moisture are discussed later in this report.

Table 2 - Average Approximate Cattle Water Intake for Winter Period at well 10A-5-W06

	Dec	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Average**
	Pregnant Cows (Dec – Mar) and Cow-Calf Pairs (Mar – Jun)							
Mean Monthly Temp (°F) [a]	31.0	30.2	34.1	39.7	46.3	55.0	63.9	42.9
Gallons per lb. DMI [b]	0.37	0.37	0.37	0.37	0.39	0.43	0.49	0.4
DMI (lb/day) [c]	19.8	19.8	19.8	19.8	31	31	31	24.6
Base Water Intake (gpcd) [d]	7.3	7.3	7.3	7.3	12.1	13.3	15.2	10.0
Milk Production (lb/day) [e]	0	0	0	0	16.7	20	18	7.8

	Dec	Jan	Feb	Mar	Apr	May	Jun	Average
Water Intake for Milk (gpcd) [f]	0	0	0	0	1.7	2.1	1.9	0.8
Total Water Intake (gpcd) [g]	7.3	7.3	7.3	7.3	13.8	15.4	17.1	10.8

[a] Fence Lake weather station (WRCC, 2016)
[b] Winchester and Morris, 1956; interpolated based on temperatures
[c] DMI 19.8 lbs/day for pregnant cows and 23.4 lbs/day for bulls (Winchester and Morris, 1956), 31 lbs/day for a cow-calf pair consuming 2.58% of BW per day (Meyer et al. 2012).
[d] Water intake based upon DMI
[e] Milk production for a peak production of 20 pounds per day for a 1,000 cow (Gadberry, 2002)
[f] Assuming 0.87 pounds of water intake per pound of milk produced (Winchester and Morris, 1956)
[g] Total water intake including additional water for milk production.

3.2.3 Water Requirements – Summer Period

The summer periods, as described by Mr. Cox, consisted of cow-calf pairs and bulls moving to the upper elevations near the Rincon Hondo in July and remaining there until the cattle are rounded up in November. Thus, water requirements for this period consider both the cow-calf pairs and the bulls. The DMI of cow-calf pairs is estimated as 31 pounds per day as previously discussed. The DMI of bulls is 23.4 pounds assuming 1,600-pound live weight (Winchester and Morris, 1956). Again, applying the water intake rates from Winchester and Morris corresponding to the monthly mean temperature and DMI, the average water intake during this period is computed to be 14.8 gpcd for each cow-calf pair and 10.7 gpcd for each bull as shown in Table 3.

Table 3 - Average Approximate Cattle Water Intake for Summer Period at well 10A-5-W06

	Jul	Aug	Sep	Oct	Nov	Average
			Cow-Calf Pairs			
Mean Monthly Temp (°F) [a]	69.4	66.9	60.6	49.9	38.6	57.0
Gallons per lb. DMI [b]	0.53	0.51	0.46	0.40	0.37	0.5
DMI (lb/day) [c]	31	31	31	31	31	31.0
Base Water Intake (gpcd) [d]	16.6	16.0	14.4	12.4	11.5	14.2
Milk Production (lb/day) [e]	14.4	10.8	7.8	0	0	6.6

	Jul	Aug	Sep	Oct	Nov	Average
Water Intake for Milk (gpcd) [f]	1.5	1.1	0.8	0	0	0.7
Total Water Intake (gpcd) [g]	18.1	17.1	15.2	12.4	11.5	14.8
Bulls (1,600 lbs. mature weight)						
DMI (lb/day)	23.4	23.4	23.4	23.4	23.4	23.4
Total Water Intake (gpcd)	12.5	12.0	10.9	9.4	8.7	10.7

** Refer to Table 2 for table footnotes

3.2.4 Daily Values Compared with Mr. Fredrickson's Report

There are a couple of factors which result in lower water intake values as computed in the tables above than in Mr. Fredrickson's analysis. First, Mr. Fredrickson applies the peak lactation rates of "cows nursing calves, 3-4 months after parturition" from Winchester and Morris (1956) to the entire nursing period (Fredrickson, 2016c, p. 44). However, Milk production declines after this peak period as demonstrated by lactation curves presented by NRC (2000) and monthly milk production values presented in Gadberry (2002).

Second, Mr. Fredrickson simply adds any water intake by the "calves" to the lactating cows disregarding if the total DMI of these animals are consistent with his definition of animal unit. This also does not consider any water provided to the calves in the milk. As previously mentioned, each pound of milk is estimated to contain 0.87 pounds of water (Winchester and Morris, 1956) To arrive at his peak water intake rate of 24.05 gallons per cow-calf pair per day (Fredrickson, 2016c, Figure 16), he sums the water intake of a lactating cow and three classes of calves. Mr. Fredrickson has previously stated his analysis considers a cow-calf pair of 1.00 AU with a forage demand of 26 pounds per day (Fredrickson, 2016c, pp. 33-34). According to the tables in Winchester and Morris (1956), cattle consume approximately 0.54 gallons of water per pound of DMI at a mean temperature of about 70°F. Thus, a peak water intake of 24.05 gallons per day, less 2.1 gallons for additional intake due to peak milk production, corresponds to approximately 40 pounds of DMI for the cow-calf pair, not the 26 pounds used by Mr.

Fredrickson in his forage analysis. There is no apparent connection between Mr. Fredrickson's forage analysis, water intake analysis, and the publications upon which he relies for water intake rates.

Finally, Mr. Fredrickson develops and uses an "ambient daytime temperature" (Fredrickson, 2016c, p. 42-43) to determine which water intake values to apply on any given day. As previously discussed, neither NRC (2000) nor Winchester and Morris (1956) present such a procedure. As previously discussed, the water consumption of cattle is predicted by using mean temperature data (Winchester and Morris, 1956). Mr. Fredrickson's approach increases estimated water intake and does not appear to have any particular basis.

3.3 Total Water Intake vs. Free Water Intake

The values in the water intake tables in NRC (2000) or Winchester and Morris (1956) represent total water intake of the animal. Winchester and Morris state that "[t]he information presented in figure 1 and table 1 is given in terms of total water intake which includes both the water drank and the water contained in feed." The authors to go on to provide methodology for reducing the total free water intake requirements to account for water provided in feed. Typically growing pasture forage grazed by animals has higher moisture content than that provided as dried feeds such as hay (NRC, 2000). The moisture content in growing vegetation varies based upon type, setting, stage of growth, and climate conditions (NRCS, 2006). Exhibit 4-2 in the *Range and Pasture Handbook* presents typical air-dry matter values as a percentage of green weight[2]. The grasses category is shown to range from 30% to 80% DM during growing stages and 85% to 95% DM during dry and dormant periods.

Mr. Fredrickson quotes Winchester and Morris (1956), saying that "the difference between total water intake, which includes moisture content of the feed, and free water intake is small, and in practical situations can be ignored" (Fredrickson, 2016c, p. 41). The context of this quote is referring to animals on dry feeds. Winchester and Morris state the opposite when it

[2] Green weight is the total weight of the plant material as harvested from the field before drying (NRCS, 2006).

comes to animals grazing pasture or consuming feeds higher in moisture. The context of their statement is given below:

> When the ration consists of hay, grain and similar "dry" feeds that are about 10% moisture, cattle ordinarily obtain only a third of a gallon or less of water a day from the rations. Because this amount is small, in practical situations the difference between total water intake and free water consumption often can be ignored and the water intake rates given by table 1 used to represent free water consumption.
>
> …
>
> In contrast with the small amount of water ingested in hay and grain, the water included in the feed when cattle are on pasture or consuming silage or other succulent feeds may amount to a large part of the animals' water requirement. (Winchester and Morris, 1956)

Mr. Fredrickson refers to the water intake he computes for the cow-calf pair as “free water intake” (Fredrickson, 2016c, p. 48). This is simply not the case. By disregarding any moisture contained in the forage vegetation, Mr. Fredrickson’s analysis again overestimates the free water intake by cattle grazing on rangeland. In addition to the quote above, Winchester and Morris (1956) discusses procedures and provides a formula to adjust cattle water intake to account for moisture in feed. As an example demonstrating this concept, if a 1,000 pound cow with a DMI requirement of 18.9 pounds per day (Winchester and Morris, 1956) is grazing on pasture consisting of vegetation with a DM content range similar to the 30% to 80% shown in NRCS (2006), the animal would also consume anywhere from 4.7 to 44.1 pounds (0.6 to 5.3 gallons) of water from feeding alone. This water goes towards satisfying the total daily water intake requirement of the animal. If this 1,000 pound cow would normally require a water intake of 10.2 gallons per day at 70°F (Winchester and Morris, 1956), then the free-water intake is reduced to 4.9 to 9.6 gallons in this hypothetical situation. This is a reduction in free-water drinking anywhere from approximately 5% up to 50%, depending on moisture content. Mr. Fredrickson’s analysis assumes that the animals do not satisfy any portion of their drinking requirement by water contained in the vegetation leading to an overestimate of free water intake.

4 Operational Losses

Mr. Fredrickson has provided an accounting of theoretical operational losses he believes to be associated with well 10A-5-W06 (Fredrickson, 2016c, p. 68). In many of these cases it is not clear what criteria or measurements Mr. Fredrickson used to form these opinions or he appears to base his analysis on intermittent personal observation. He does not provide or reference any specific records, measurements, or studies associated with the well in support of the total claimed water loss. The total operational loss at well 10A-5-W06 is estimated by Mr. Fredrickson to be 415,522 gallons (1.275 acre-feet) per annum.

4.1 Drinking Losses

In his report, Mr. Fredrickson applies an estimated loss of 5% to account for spillage when the cattle are drinking (Fredrickson, 2016c, pp. 55-56). However, this loss is already accounted for in the water intake requirements used in his calculation. The cattle water intake quantities applied by Mr. Fredrickson from NRC (2000) are based upon the research of Winchester and Morris (1956). Winchester and Morris applied research from Ragsdale et al. (1951) who reported that “the given water consumption data represents the total amount supplied to the water cups, including spillage from lapping and slobbering.” Winchester and Morris noted that “only a small fraction [of water] is wasted, even at high ambient temperatures.” Mr. Fredrickson is double-counting these losses since they are already included in the initial water intake rates on which he uses in his livestock water calculation.

4.2 Trough Cleaning

Mr. Fredrickson asserts that routine maintenance requires cleaning of the watering troughs by fully emptying and rinsing twice per week (Fredrickson, 2016c, p. 56). Mr. Fredrickson reports there are a total of five drinking troughs with a combined volume of 108.71 ft^3 (Fredrickson, 2016c, p. 7). Citing a practice at a 50,000 head feedlot operation in Texas which would rinse troughs every 2-3 days (Parker et al., 2000), Mr. Fredrickson simply asserts that a twice per week cleaning schedule throughout use period is reasonable. This cleaning approach was not historically engaged by the owner and operator, Mr. Cox, who has stated that he never cleaned the trough at this well (Cox Dep., 2016, p. 52). This stated water use by Mr. Fredrickson is not based upon any known historical practice associated with well 10A-5-W06.

Furthermore, the material cited by Mr. Fredrickson does not appear to be typical practice even at the average feedlot. Based on data provided by 520 feedlots throughout the central and western United States, the average number of days between routine cleaning of water troughs is 12.7 days in in the summer to 15.7 days in the winter with larger feedlots (8,000+ head) cleaning troughs approximately twice as often as small feedlots (APHIS, 2000). Mr. Fredrickson's proposed cleaning schedule of twice per week is far more frequent than the reported typical feedlot cleaning practice of about once every two weeks. No information is provided by Mr. Fredrickson specific to well 10A-5-W06 to demonstrate that a twice per week cleaning schedule has ever been the historic practice and it is directly contradicted by Mr. Cox's statements.

4.3 Weep Hole Discharge

In his report, Mr. Fredrickson claims there are losses associated with a purported weep hole which allows drainage to prevent water freezing in the well pipe. Mr. Fredrickson has not directly observed or measured the hole; his assertion is based on his claim of "routine practice" and purported observations of water drop in the well pipe (Fredrickson, 2016c, p. 58). This is the largest component in Mr. Fredrickson's loss estimate totaling 165,652 gallons per annum or 0.51 acre-feet per annum. Mr. Fredrickson has concluded that well 10A-5-W06 is equipped with a 1/8" diameter weep hole at 4-feet below the ground surface (Fredrickson, 2016c, p. 58). Mr. Fredrickson does not state how he distinguished between water level drop in the pipe caused by a weep hole and that of any water returning through the valves and pump mechanism itself back to groundwater. Mr. Fredrickson also computes weep hole discharge when wind is powering the pump. Mr. Cox described that he did not leave the windmill operating continuously, particularly when the water demand was low (Cox Dep., 2016, p. 50). As a result, even assuming the existence of this weep hole, Mr. Fredrickson overestimates the amount of water discharged from it.

In addition, an operational loss describes any water that is pumped from the well which does not go towards satisfying an animal's water intake requirement. Considering the configuration of the well and this weep hole as it is described by Mr. Fredrickson, discharge of water through the hole is not "lost" in the same sense as, for example, spillage or evaporation. If the water is discharged from the pipe through a weep hole as stated by Mr. Fredrickson, then it would flow directly into the well casing and returns to the groundwater at the bottom of the borehole. The water simply keeps circulating in the pumping system and therefore is not an operational loss.

4.4 Trough Leakage

Mr. Fredrickson assumes a loss of 52,560 gallons per year which is associated with chronic leakage from the main holding tank and watering troughs. He states that his observations of water level drop in the main tank lead him to conclude the leakage rate is 0.1 gallons per minute. This rate of leakage would not be constant and would depend upon where the leak(s) occur and the water level in the tanks at any given time. Mr. Fredrickson does not provide any record, measurements, or calculation demonstrating this leakage rate or how he apparently corrected for other loses such as evaporation and wildlife usage. Several photographs are provided (Fredrickson, 2016c, p. 61) showing that some components of the water delivery system may have leaked at some time. However, these photographs do provide a basis for a rate of 0.1 gallons per minute. Mr. Cox stated that he did not remember the drinkers having any leaks during the time he operated the ranch (Cox Dep., 2016, p. 75).

4.5 Ice Removal

Based upon the statements made by Mr. Cox, Mr. Fredrickson produces an estimate for the water loss due to ice removal from the troughs in the winter (Fredrickson, 2016c, p. 62). Mr. Cox stated that they generally would remove and discard the ice that formed in the troughs once every two days from mid-December to March (Cox Dep., p. 64). Of course, ice only needs to be removed if conditions were such that it formed. Mr. Fredrickson estimated that 4 inches of ice would need to be removed at each clearing period every other day from December 15th to March 1st. No records or measurements are provided in support of the 4 inches of assumed ice thickness.

The total water loss associated with 4 inches of ice being cleared every two days for the season, or 37 times per year, is computed by Mr. Fredrickson to be 6,917 gallons.

Simplified procedures exist to estimate accumulated ice thickness as a function of daily mean air temperature (USACE, 2002). Ice will accumulate when the mean daily temperature is below freezing (32°F) with the total ice accumulation relating to how far below freezing mean temperatures fall. The Freezing Degree Day (FDD) is computed as FDD = 32 - T_{avg}. For a 48-hour period, the accumulated FDD (AFDD) is the sum of the FDD for the two days. Ice thickness, t, is then computed as $t = C\sqrt{AFDD}$ with C representing various ice cover conditions. This model is considered to be an approximation of the relationship of the actual heat transfer mechanisms yet is considered to be a “good, practical model of ice growth” (USACE, 2002). Local calibration of “C” to measured ice thicknesses at well 10A-5-W06 would improve this analysis. Mr. Fredrickson did not apply any apparent method to estimate ice growth or thickness at the well.

Mean daily temperate (T_{avg}) time series data is available for the period 1981 – present day (PRISM, 2016). In an average year, the FDDs begin consistently accumulating in mid-December and lasting into February of the following year. An every-other-day ice cleaning schedule results in 37 clearings during this period. Using the above ice growth model, the mean ice thickness over each 48-hour period is about 1.4 inches. The mean maximum thickness is 2.5 inches and the sum of total mean ice accumulation over the season assuming 37 clearings is 51 inches. This accumulation assumes any ice buildup is removed every other day. Considering the density relationship between ice and water, the water equivalent of 51 inches of ice is about 46.7 inches of water per annum. In the coldest winter in the 1981-2014 record, winter of 2009-2010, the average ice thickness is estimated to have been about 2.5 inches at each clearing following the USACE method. Both of these cases are less than the 4 inch thickness assumed by Mr. Fredrickson.

4.6 Evaporation

Mr. Fredrickson bases his total evaporative loss upon the number of troughs and net surface area that exist on the property today (Fredrickson, 2016c, p. 68). Mr. Cox described that there were only two permanent drinking tanks, in addition to the regulation tank and main tank, during the time he operated the ranch (Cox Dep., 2016, p.73 and Exhibit D). In light of Mr. Cox's description, the evaporation (and ice clearing) quantities estimated by Mr. Fredrickson would overestimate these water losses during the time Mr. Cox operated cattle at the well.

4.7 Wildlife Watering

In his report, Mr. Fredrickson assumes that deer and elk consume 39,694 gallons per annum (0.122 acre-feet per annum) from well 10A-5-W06. This wildlife loss is based upon his estimate of deer and elk on the property today and their associated animal water consumption. Mr. Fredrickson does not provide any records or studies of the immediate area to support his assumption that 15 mule deer and 20 elk visit the well daily for 75% of the year (Fredrickson, 2016c, 66). While the photographic evidence provided by Mr. Fredrickson clearly demonstrates that animals other than cattle drink from the well, no apparent basis for his specific number of animals is provided.

Furthermore, the behavior of the wildlife would likely be affected by a large cattle herd in the area, such as the 200 cattle herd described by Mr. Cox during his deposition. Mr. Fredrickson's assumptions for wildlife are not consistent with wildlife activities when cattle are present. A study found that cattle presence cause changes in distributions of both elk and mule deer (Coe et al., 2000). Cooper et al. (2008) proposes that, because deer appear to avoid close contact with cattle, watering sources for deer and wildlife should be placed in areas that cattle are less likely to access. Thus, even if Mr. Fredrickson's animal counts could be verified, there is no basis to assume that those numbers are representative of wildlife use at the well during historic cattle operations.

5 Total Historic Livestock Water Use

The total historic livestock water quantity can be computed for well 10A-5-W06 based the known ranch operation as described by Mr. Cox, published water intake rates for cattle, and any known and quantifiable losses associated with the well watering process. These items are tabulated below in Table 4 and Table 5.

5.1 Livestock Water Intake

The following computations assume a maximum herd size of 220 cattle, including 200 cow-calf pairs/pregnant cows, and a bull to cow ratio of 1:10 resulting in 20 additional bulls. Also, assumptions can be made from Mr. Cox's descriptions to the number of cattle on well 10A-5-W06 throughout the season: 40% of the herd for the winter months and 1/3 of the herd during the summer months. Although Mr. Fredrickson argues, based on his hypothetical forage analysis, that all cattle will remain at well 10A-5-W06 during the summer, Mr. Cox stated that the cattle used all watering sources in the area. As such, it is assumed the cattle utilize all three summer water sources equally (Rincon Hondo well a/k/a 10A-5-W06, Perry Canyon well, and High Lonesome well). This does not include any water obtained by the cattle from Zuni Spring[3] or any other watering sources which may be available in the area such as water in natural depressions or man-made impoundments. Total estimated water use associated with historic livestock use at well 10A-5-W06 is 1.067 acre-feet per annum as shown in Table 4.

[3] Unlike wells, springs are naturally occurring features with water discharge that may vary seasonally or over the course many years. In contrast to the man-made wells, Zuni Spring is considered a natural feature and is therefore excluded from this analysis as a potential watering source.

Table 4 - Estimated Annual Historic Livestock Use of Well 10A-5-W06

Item	Average Use Rate (gpcd)	Cattle Count	Days	Historic Use (gallons)	Historic Use (acre-feet)
Pregnant Cows & Cow- Calf Pairs Winter, Dec - Jun	10.8	80	213	184,069	0.565
Cow-Calf Pairs Summer, Jul - Nov	14.8	67	153	152,197	0.467
Bulls Summer, Jul - Nov	10.7	7	153	11,447	0.035
				Total	1.067

5.2 Operational Losses

There are two known losses of water associated with well 10A-5-W06 which can be quantified and included as part of the historic water use. These losses are evaporation and ice removal practices as discussed by Mr. Cox (Cox Dep., 2016, p. 66). NRCE does not have any reliable information regarding any other historic losses associated with well 10A-5-W06. These losses total 0.037 acre-feet per annum as shown in Table 5. Note that the surface areas in the table are based upon the drinkers Mr. Cox said existed during the ranch operation (Cox Dep., 2016, Exhibit D) and not the combined area of Mr. Fredrickson's current drinker configuration.

Evaporation loss is estimated using data provided in the Evaporation Atlas of the United States (NOAA, 1982). The evaporation contour lines over the Fredricksons property and Zuni River Basin area indicate that the average annual evaporation for a shallow lake is about 50 inches per annum. Since the troughs sit above ground it is reasonable to treat them similar to an evaporation pan which usually show higher evaporation than an in-ground ponds or lakes. Applying a typical pan coefficient of 0.75 (WRCC, 2016b), the total evaporation from the troughs is estimated as 66.7 inches per year. Subtracting out the average precipitation of 14.1 inches (Fence Lake, WRCC 2016a), the net evaporation is approximately 52.3 inches per year. This is similar to the evaporation quantity used by Mr. Fredrickson in his analysis (Fredrickson, 2016c, pp. 63-64). Additionally, water lost due to ice removal is computed as previously discussed assuming a seasonal ice thickness accumulation of 46.7 inches per annum.

Table 5 - Estimated Annual Historic Water Losses at Well 10A-5-W06

Item	Depth per year (in)	Surface Area (sq-ft)	Total Use (gallons)	Total Use (acre-feet)
Evaporation	52.5	271.27	8,885	0.027
Ice Removal	46.7	61.83	1802	0.006
			Total	0.033

The total annual water quantity based upon historic livestock use at well 10A-5-W06 is estimated to be approximately 1.100 acre-feet per annum. Including a domestic use of 0.7 acre-feet per year, the total quantity for well 10A-5-W06 is then 1.800 acre-feet per year.

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Appendix A – Resume of Scott Turnbull

Scott Turnbull, P.E.
ASSOCIATE ENGINEER

Mr. Turnbull is an associate engineer at NRCE and holds a B.S. in Civil Engineering. Mr. Turnbull has over eight years of experience in water resources and agricultural engineering. His engineering experience includes water system design, hydraulic analysis, estimation of crop irrigation and diversion requirements, estimation of livestock water use, water resources planning, field work for surveying and documentation of water features and associated uses, cost estimation, and providing analysis for domestic, irrigation, livestock, and municipal water use studies.

EMPLOYMENT HISTORY

Associate Engineer * January 2013 - Present
Assistant Engineer * December 2007 – December 2012
Natural Resources Consulting Engineers, Inc. * Fort Collins, CO

- Calculates evapotranspiration, crop irrigation requirements, project diversion requirements, and develops irrigation schedules.
- Performs system design for irrigation works including pressurized pipe, pump sizing, gravity lines, canal design, earthwork, site grading, and selection of surface and subsurface irrigation systems for various applications.
- Estimates capital and annualized costs associated with engineering designs for water systems.
- Evaluates irrigation system efficiencies and provides recommendations for water saving opportunities.
- Determines domestic, commercial, municipal, industrial (DCMI) and livestock water needs.
- Carries out surface water hydrologic modeling and analysis
- Conducts field visits for data collection and verification of land use and water features.
- Performs various geospatial (GIS) tasks including data collection, mapping, and geospatial analysis.
- Assists in litigation support for water right claims
- Provides support in the formulation of technical memoranda, reports, and project cost estimations.

Engineering Intern II * 2006 & 2007
City and County of Denver, Denver International Airport * Denver, CO

- Conducted preliminary structural analysis for architectural planning.
- Designed tarmac equipment structures for aircraft and worked with the steel fabricator during construction and installation of these units on concourse aprons.
- Contacted contractors and coordinated site visits on Denver International Airport property.
- Reviewed project drawings, specifications, contractor submittals, and information requests for the Terminal West Mod 4 Parking Structure.
- Runway Pavement Assessment Program - Examined runway concrete panels for damage, recorded locations using GPS and GIS software, and recommended repair procedures.

EDUCATION

B.S., Civil Engineering
Colorado State University
Fort Collins, CO, 2007.

PROFESSIONAL REGISTRATIONS

Professional Engineer
Colorado #47227, 2012

RELEVENT COMPUTER SKILLS

- ESRI ArcGIS
- AutoCAD
- MS Office Suite
- MS Visual Basic Programming for Applications
- Computer Modeling

PROFESSIONAL ASSOCIATIONS

American Society of Civil Engineers