WATER USE AND CONSERVATION AT TEXAS HIGH PLAINS BEEF CATTLE FEEDYARDS

D. B. Parker, L. J. Perino, B. W. Auvermann, J. M. Sweeten

ABSTRACT. *Water conservation in the Texas High Plains has become increasingly important as groundwater resources are depleted. A water usage study was performed over a two-year period at a 50,000-head beef cattle feedyard. Water usage was correlated to meteorological data from a NOAA weather station. Average daily water usage over the two-year period was 40.9 L/head/d (10.8 gal/head/d). Whenever water trough floats were adjusted for winter conditions, 66% of total usage was for drinking, 2% was used in the feedmill, and 32% was used for overflow to prevent freezing. Whenever water trough floats were adjusted for summer conditions, 89% was used for drinking, 3% was used in the feedmill, and 7% leaked into the overflow collection system. Options identified for conserving water include installing more efficient water troughs, repairing existing troughs, and installing an overflow recycling system. Potential beneficial uses for the overflow water include irrigation of crops, sprinkling pens for dust and temperature control, and use in steam flaking of grain at the feedmill. If all of the overflow water were recycled at this feedyard, then 162 000 m^3 (42.7 million gal) would be conserved per year (22% of total annual use). Construction of a $39,000 filtration-chlorination water treatment system would have a payback period of six years at 8% interest, and result in a net monthly savings of $707 after payback of the capital investment.*

Keywords. *Water usage, Conservation, Feedyard, Arid regions, Drinking, Water trough, Waterer, Feedlot, Overflow, Recycle.*

More than 6 million beef cattle are fed each year at feedyards in the Texas High Plains area of the United States (SPS, 1997). As groundwater supplies become more critical in the semiarid cattle feeding area of the Texas High Plains, water conservation measures are important to feedyards and other water users. The main water consumption source at feedyards is cattle drinking.

Researchers have shown that environmental factors such as temperature, relative humidity, and wind speed influence animal physiology, thereby affecting drinking rates. Temperature humidity indices (THI) have been developed to relate animal heat stress to environmental indicators for several animal species (Buffington et al., 1981; Roller and Goldman, 1969). Winchester and Morris (1956) compiled water consumption data for dairy and beef cattle based on temperature, body weight, and production stage of the animals. Hicks et al. (1988) developed a regression equation for water consumption by feedlot steers based on temperature, dry matter intake, precipitation, and dietary salt (NRC, 1996). Parker et al. (1998) developed regression equations for beef cattle feedyard water use based on daily temperatures monitored at 6:00 A.M. and 5:30 P.M. at the feedyard. Other researchers have evaluated water intake in beef and dairy cattle as related to salinity (Kattnig et al., 1992), sulfate concentration (Robertson et al., 1996), and season of the year (Hoffman and Self, 1972).

Feedyards provide drinking water to cattle 24 h/day in water troughs placed in each pen, with 50 to 200 cattle per pen typical of most yards. Water is supplied through pressurized pipelines to float mechanisms that maintain a constant water level in the trough. During the winter, there is the potential for ice buildup in the troughs that prevents cattle from access to water and damages plumbing. Water trough manufacturers sell a wide range of water trough types designed to prevent ice buildup problems, including overflow water troughs, electrically heated troughs, "thermal cap" or floating ball type troughs, "recirculating" troughs, and "suction tube" type troughs (Anderson and Johnson, 1987). Standards exist for safety of electrically heated livestock water troughs (ASAE, 1999).

The four most common types used in Texas High Plains feedyards are the standard overflow trough (water flows continuously through the trough when the valve is opened), the temperature-controlled overflow trough (water flows through the trough controlled by a thermostat-type valve), the non-overflow trough (electrically heated), and the ball-type (floating plastic ball). Schematics of each are shown in figure 1.

In a recent survey of 55 feedyards in the region, 33 feedyards reported using standard overflow troughs, 11 reported using temperature-controlled overflow troughs, six had non-overflow troughs, three reported ball-type troughs, and the remaining two reported troughs of some

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Article was submitted for publication in November 1998; reviewed and approved for publication by the Structures & Environment Division of ASAE in November 1999. Presented as ASAE Paper No. 98-2138.

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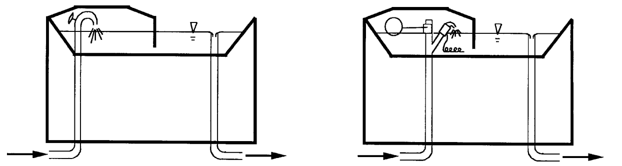
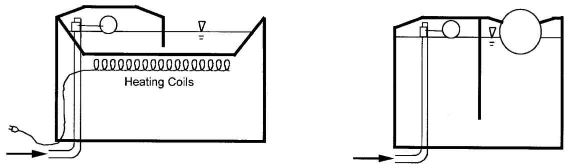


Continuous overflow water trough. Water level is regulated by height of standpipe. Overflow is regulated by faucet or float valve setting.

Temperature-controlled overflow water trough. Water level is regulated by height of standpipe. Overflow is regulated by thermostat-controlled valve that opens when cold and closes when warm.



Non-overflow heated trough. Water is heated with electricity to prevent freezing. Water level is regulated by float valve setting.

Ball-type water trough. Water level is regulated by float valve. Cattle push floating plastic ball down to gain access to water for drinking. Closed system prevents water from freezing.

Figure 1–Schematics of four types of water troughs used at Texas High Plains beef cattle feedyards.

other type (Texas Cattle Feeders Association, 1997, unpublished data).

Because of the importance of water conservation in the semiarid area, a water usage study was conducted at a large feedyard. The objectives of the study were to measure the amount of water used at a typical feedyard, develop relationships for water usage with atmospheric conditions, and identify options for conserving water at feedyards.

MATERIALS AND METHODS

DESCRIPTION OF THE FEEDYARD

The project was conducted at a feedyard with a one-time feeding capacity of about 50,000 head. The feedyard uses standard overflow water troughs with floats that are adjusted for continuous overflow during the winter. Water usage is metered by the water authority with a propeller-type flowmeter upon entering the yard (fig. 2). Water is stored on-site in a 2800-m^3 (750,000-gal) storage tank. The water level in the large tank is controlled with a pump and water elevation switches. The water flows from the large tank into the feedyard/feedmill water supply system. Pressure on the delivery system is regulated with a pump and water elevation switches in the 114-m^3 (30,000-gal) storage tank.

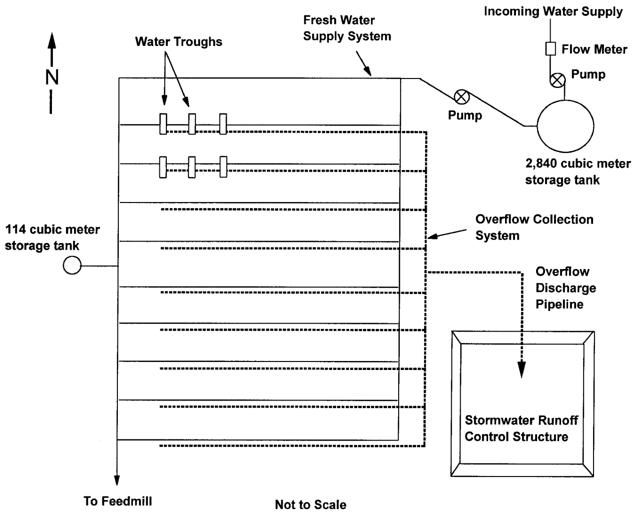


Figure 2–Layout of the feedyard water supply and overflow collection systems.

Each water trough is supplied through a 5.1-cm (2-in.) diameter pipeline fed from both sides of the feedyard. Overflow from each trough flows into 5.1-cm-diameter drainage pipelines which eventually flow into two, 20.3-cm (8-in.)-diameter drain lines and into the stormwater runoff control structure.

DATA COLLECTION

The flowmeter at the incoming water supply was monitored daily from November 1995 through October 1997 to determine total daily water usage for the entire feedyard. Additionally, overflow was monitored over two 72-h periods, first when floats were adjusted for winter conditions (17-20 April 1997), and again when floats were adjusted for summer conditions (9-12 May 1997). The overflow data was collected every 20 min using an electronic flowmeter and datalogger (Polysonics Inc., Model TF-P).

Weather data was obtained from a National Oceanic and Atmospheric Administration (NOAA) weather station located 50 km north of the feedyard. The following meteorological parameters were available: daily maximum temperature (°C), daily minimum temperature (°C), daily maximum relative humidity (%), daily minimum relative humidity (%), average daily dew point (°C), average daily atmospheric pressure (kPa), average daily wind speed (m/s), and daily precipitation (cm).

Correlation analyses, multilinear regression, and nonlinear regression techniques were used to evaluate various equations for predicting total daily feedyard water usage based on these meteorological parameters. Multilinear regression analyses was performed using the forward selection method of Snedecor and Cochran (1989). Using this method, the first step consisted of performing linear regression on each variable, then selecting the variable with the smallest residual mean square. This was followed by regressions on all remaining variables and stepwise selecting the variables that gave the greatest additional reduction in the sum of squares after fitting the first variable. A 5% significance level was used for determining if the additional variables should be added.

We observed that a quadratic relationship existed between maximum temperature and water usage. Therefore, in addition to multilinear regression techniques, nonlinear regression was also used to develop and evaluate relationships between water usage and many combinations of meteorological parameters. All statistical analyses were performed using SPSS version 6.1.3.

RESULTS AND DISCUSSION

WATER USAGE DURING THE TWO-YEAR PERIOD

Because of the large on-site storage tank, which held more than one day's supply of water, the amount of water supplied to storage varied greatly from 0.0 to 79.5 L/head/d (0.0 to 21.0 gal/head/d). Moving averages were used to smooth the storage volume effect. Moving averages are the simple average of the most recent data points (Berthouex and Brown, 1994). For our data, five-day moving averages were found to be the minimum length of time at which the memory of the system was minimized (Berthouex and Brown, 1994).

The five-day moving averages ranged from 18.5 to 61.7 L/head/d (4.9 to 16.3 gal/head/d). A plot of daily water usage using five-day moving averages is shown in figure 3.

Two water usage peaks were observed per year, one during the winter months and another during the summer months. The peak in the summer was attributed to increased consumption by cattle because of elevated temperatures, while the peak in the winter was because of high overflow rates to prevent ice formation in water troughs. Total water usage for the two-year period averaged 40.9 L/head/d (10.8 gal/head/d).

WATER TROUGH OVERFLOW DURING WINTER AND SUMMER CONDITIONS

Overflow rates ranged from 254 to 844 L/min (67 to 223 gal/min) when floats were adjusted for winter conditions, and 45 to 182 L/min (12 to 48 gal/min) during summer conditions (fig. 4). Overflow was present in the summer because of leakage where the overflow pipes were threaded into the bottom of the trough. The average overflow rate for the three day period was 579 L/min (153 gal/min) for winter conditions and 121.1 L/min (32 gal/min) for summer conditions. Cattle drank the most from 12:00 P.M. to 4:00 P.M., when overflow was the least, and they drank the least at 6:00 A.M. in the morning, when overflow was the greatest.

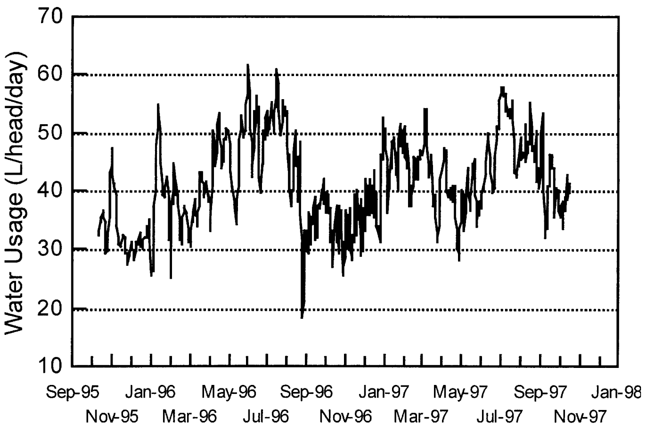


Figure 3–Feedyard total daily water usage for two-year period from November 1995 to October 1997. Values plotted are five-day moving averages to smooth variability caused by storage volume effects.

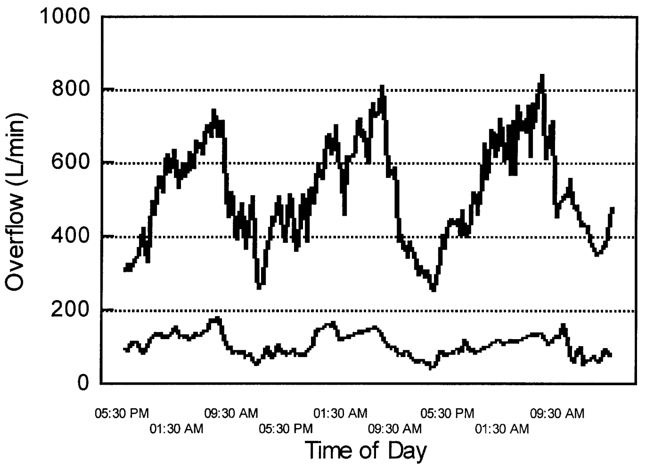


Figure 4–Water trough overflow with floats adjusted for winter conditions (top line), and summer conditions (bottom line).

Water troughs are cleaned about every three days during the winter and every two days in the summer. About 42.5 m^3 (11,200 gal) were drained at every cleaning, which equates to 14.2 m^3/d (3,750 gal/d) during the winter and 21.3 m^3/d (5,620 gal/d) during the summer. With an average annual evaporation rate of 0.51 cm/d (0.2 in./d) and 0.84 m^2 (9.0 ft^2) water surface area per water trough, then about 1.1 m^3 (300 gal) was lost per day to evaporation. The average daily water use at the feedmill, as measured with a dedicated in-line propeller-type flowmeter, was 55.8 m^3/d (14,750 gal/d) in April and 73.0 m^3/d (19,300 gal/d) in May. An average of 1.5 L/head/d (0.40 gal/head/d) was used in the feedmill based on 12 months of available feedmill water use data.

For the three-day period representing winter conditions, an average of 51.8 L/head/d (13.7 gal/head/d) was used at the feedyard (water usage measured at pump between large tank and feedyard to minimize storage volume effect). Of this total, 34.1 L/head/d (9.0 gal/head/d or 65.6%) was used for drinking, 0.3 L/head/d (0.08 gal/head/d or 0.55%) was used for cleaning troughs, 1.1 L/head/d (0.30 gal/head/d or 2.16%) was used in the feedmill, 0.02 L/head/d (0.006 gal/head/d or 0.04%) was lost to evaporation, and 16.4 L/head/d (4.33 gal/head/d or 31.68%) was attributed to overflow to prevent freezing.

For the three-day period representing summer conditions, an average of 43.9 L/head/d (11.60 gal/head/d) was used (water usage measured at pump between large tank and feedyard to minimize storage volume effect). Of this total, 39.0 L/head/d (10.3 gal/head/d or 88.97%) was used for drinking, 0.3 L/head/d (0.08 gal/head/d or 0.65%) was used for cleaning troughs, 1.5 L/head/d (0.39 gal/head/d or 3.35%) was used in the feedmill, 0.02 L/head/d (0.006 gal/head/d or 0.05%) was lost to evaporation, and 3.1 L/head/d (0.81 gal/head/d or 6.98%) was attributed to leakage losses into the overflow collection system.

RELATIONSHIPS BETWEEN WATER USAGE AND METEOROLOGICAL PARAMETERS

Pearson's correlation coefficients, which measure the strength of the linear relationship between water usage and meteorological parameters, are shown in table 1. There was a significant correlation between water usage and all meteorological parameters except for minimum relative humidity and precipitation.

The best fit forward selection multilinear regression equation (SI units) was:

$$\begin{aligned} \text{DWU} &= -213.0 + 0.633\ \text{MAXT} - 0.0728\ \text{MINRH} \\ &\quad + 2.76\ \text{BARPRES} \quad r^2 = 0.47 \end{aligned} \tag{1}$$

where

DWU = daily water use (L/head/d)
MAXT = maximum daily temperature (°C)
MINRH = minimum daily relative humidity (%)

Table 1. Pearson's correlation coefficient matrix of weather parameters and water use

	Water Use	Max T	Min T	Max RH	Min RH	Precip	Wind	Dew Point	Bar Pres
WaterUse	1.0								
Max T	0.54*	1.0							
Min T	0.53*	0.97*	1.0						
Max RH	0.11*	0.28*	0.38*	1.0					
Min RH	–0.02	0.10*	0.24*	0.80*	1.0				
Precip	0.06	0.11*	0.13*	0.18*	0.18*	1.0			
Wind	–0.10*	–0.10*	–0.17*	–0.36*	–0.37*	–0.14*	1.0		
DewPoint	0.48*	0.90*	0.95*	0.63*	0.47*	0.18*	–0.27*	1.0	
BarPres	0.14*	–0.03	0.03	0.31*	0.33*	0.05	–0.59*	0.13*	1.0

WaterUse = Average daily water use (L/day).
Max T = Maximum daily temperature (°C).
Min T = Minimum daily temperature (°C).
Max RH = Maximum daily relative humidity (%).
Min RH = Minimum daily relative humidity (%).
Precip = Daily precipitation (cm).
Wind = Average daily wind speed (m/s).
DewPoint = Average daily dew point (°C).
BarPres = Average daily barometric pressure (kPa).
* = Correlation coefficient significantly different than zero (α = 0.05).

BARPRES = average daily barometric pressure (kPa)

The best fit forward selection multilinear regression equation (English units) was:

$$DWU = -58.4 + 0.0928\ MAXT - 0.0193\ MINRH + 0.0719\ BARPRES \qquad r^2 = 0.47 \qquad (2)$$

where
DWU = daily water use (gal/head/d)
MAXT = maximum daily temperature (°F)
MINRH = minimum daily relative humidity (%)
BARPRES = average daily barometric pressure (millibars)

A quadratic relationship was observed between water usage and maximum temperature (fig. 5). Therefore, in the nonlinear regression analyses, a squared term for maximum temperature was added. The addition of the squared term using the same two parameters of maximum temperature and minimum relative humidity increased the R^2 from 0.47 to 0.60. Addition of the other meteorological parameters in all combinations only increased the R^2 to a maximum of 0.61. The simplest nonlinear regression equation and the one easiest for commercial feedyards to apply takes the following form (SI units):

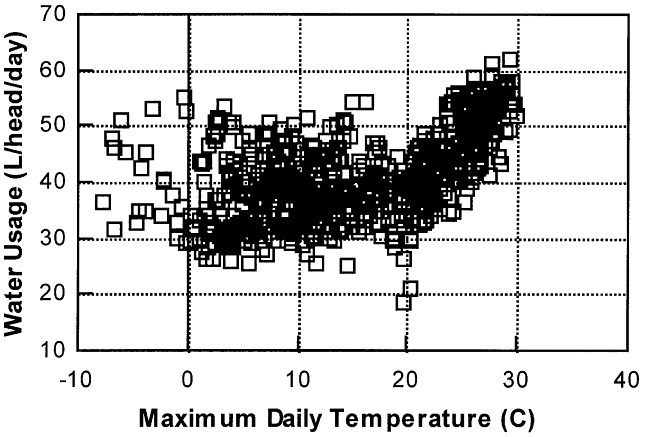


Figure 5–Graph showing relationship between maximum daily temperature and water usage for two years of data.

$$DWU = 39.2 - 0.648\ MAXT + 0.0421\ MAXT^2 - 0.0717\ MINRH \qquad r^2 = 0.60 \qquad (3)$$

where
DWU = daily water use (L/head/d)
MAXT = maximum daily temperature (°C)
MINRH = minimum daily relative humidity (%)

The best fit nonlinear regression equation (English units) was:

$$DWU = 16.9 - 0.315\ MAXT + 0.00344\ MAXT^2 - 0.0189\ MINRH \qquad r^2 = 0.60 \qquad (4)$$

where
DWU = daily water use (gal/head/d)
MAXT = maximum daily temperature (°F)
MINRH = minimum daily relative humidity (%)

From the signs of the regression coefficients, water usage increased with temperature as was expected. Water usage decreased with increasing minimum relative humidity, probably because a higher relative humidity results in less evaporation and less water vapor lost when the animals breathe. Minimum relative humidity for the two years of data ranged from 10 to 77%, with an average of 35%. Because high relative humidity can actually stress animals, these regression equations are applicable only in semiarid areas.

OPTIONS FOR CONSERVING AND RECYCLING WATER

Possible environmental and economic benefits could be realized by reducing the amount of water used at the feedyard, or recycling water that is currently lost to evaporation. Options for reducing the amount of water used at the feedyard include (1) installing more efficient water troughs, (2) installing electric tank heaters in the existing water troughs, and (3) making improvements to existing systems to reduce leakage. Options for recycling or otherwise using the overflow water include (4) recycling the water back into the drinking water system, (5) using the water for irrigation purposes, (6) using the water for dust and temperature control in sprinkled pens, and (7) using the water in the feedmill.

REDUCTION OF WATER USAGE BY INSTALLING MORE EFFICIENT WATER TROUGHS

Insulated water troughs now on the market conserve water and/or electricity as compared to non-insulated troughs. The amount of water saved would depend on the condition of the existing troughs. There are several advantages to installing new troughs, including less energy used, more water conserved, and less maintenance required. Disadvantages include expenses associated with purchasing the troughs, and reduced revenues associated with having empty pens during construction activities while installing the new troughs and new electric lines.

IMPROVEMENTS TO PREVENT LEAKAGE

By making improvements to water trough plumbing, the amount of leakage entering the overflow system could be reduced. These improvements may be easily performed in some instances, however, in older water troughs improvements could be major. The improvements would result in less water used during the summer months. Based on results at this feedyard, about 3.1 L/head/d (0.81 gal/head/d) could be conserved during summer weather conditions assuming all leakage to the overflow system could be prevented. Over a period of seven months, this would equal 32 200 m^3 (8.5 million gal) of water conserved.

RECYCLING OVERFLOW WATER BACK INTO THE DRINKING WATER SYSTEM

The overflow water could be collected and pumped back into the drinking water distribution system. For feedyards with an overflow collection system already installed, the modifications would be minor. Based on results at this feedyard, about 16.4 L/head/d (4.33 gal/head/d) were used for freeze protection during the five freezing (winter) months, which was 123 000 m^3 (32.5 million gal) of water. Leakage during the seven non-freezing (summer) months accounted for 32 200 m^3 (8.5 million gal) of water, and cleaning of tanks accounted for 6430 m^3 (1.7 million gal) of water per year. This totals 161 600 m^3 (42.7 million gal) of water per year that could be recycled.

IRRIGATION OF CROPS

Using the overflow water for irrigation would require building a storage structure for temporary storage of the water before applying to the land. The overflow water could be allowed to flow into the stormwater runoff control structure, then the combined overflow water and stormwater runoff could be used for irrigation. However, a major drawback to this approach is that feedyard runoff has elevated salt concentrations, and salinity is one of the limiting factors for land application of effluent (Sweeten, 1990).

DUST AND TEMPERATURE CONTROL IN SPRINKLED PENS

Some feedyards in the area have installed sprinklers throughout the pens. The sprinklers serve two purposes, they reduce dust emissions from the feedyard surface, and they cool the cattle during hot periods. Based on the water quality analyses of the overflow water, the overflow water could be used for sprinkling pens. Use of the overflow would require construction of a storage structure. During winter months and periods when no sprinkler water was used, other uses for the overflow water would be needed.

RECYCLING FOR USE IN THE FEEDMILL

The overflow water could be used in the feedmill for steam flaking of grain, provided that the overflow water met the water quality requirements for the mill. Some feedmills in the area currently treat their water prior to using the water for feed processing. Use in the feedmill would be site specific and dependent on the feedyard water supply and overflow water quality. The overflow water could probably be used with minor treatment, however, major treatment would probably be required before using the more contaminated feedlot runoff. For this reason, a separate storage structure would be needed for the overflow water.

ECONOMIC CONSIDERATIONS

At feedyards that rely on groundwater for their water source, groundwater pumping costs (electricity only) in the Texas High Plains range from about $29.10 to $50.20/thousand m^3 ($0.11 to $0.19/thousand gal). Total operational costs vary depending on pumping depth, pump efficiency, and electricity costs. The cost to operate booster pumps to move water and pressurize the delivery system adds another $13.20 to $42.30/thousand m^3 ($0.05 to $0.16/thousand gal), for a total water cost of between $42.30 to $92.50/thousand m^3 ($0.16 to $0.35/thousand gal).

If all of the overflow water including leakage and tank cleaning were recycled at this feedyard, then 161 600 m^3 (42.7 million gal) of water would be saved per year. Using the operating costs developed for groundwater sources, this equates to between $6,832 and $14,945/year or $569 to $1,245/month. The actual cost of overflow water at this feedyard, including pumping, is about $92.50/thousand m^3 ($0.35/thousand gal) or $1,245/month.

DESIGN OF A NEW WATER TREATMENT RECYCLE SYSTEM

A water treatment system was designed to recycle the overflow water back into the drinking water system. However, as of July 1999 the system has not been installed because of economic reasons. The treatment system consisted of an automatic backflush filter, an automated chlorinator, and all pumps, piping, and controls to pump the treated water back into the drinking water supply system. Total cost for the treatment system was estimated to be $39,000. Monthly operating costs (electricity and chlorine) were estimated to be $538, assuming water would be treated to 5 mg/L initial chlorine with $0.065/kWh for electricity. The payback period on the capital investment calculated for annual interest rates of 4, 6, 8, and 10% was 61, 65, 69, and 74 months, respectively. A net savings of $707/month would be realized after payback of the capital investment. Monthly water savings would have to be at least $538 to recover monthly operating costs. Recycle water systems may not be economical at small feedyards, feedyards with inexpensive shallow groundwater sources, or feedyards with well-designed and efficient water delivery systems.

Although a no-treatment recycle system may have some promise, feedyard operators are hesitant in returning non-treated overflow water back into the cattle drinking water system because of potential animal health issues. For example, pathogens from a sick calf would only expose one water trough using the current distribution system, but could possibly expose the entire yard if an overflow distribution system were in place. Because the viability of these pathogens is unknown, further research to determine risks from recycling drinking water is warranted.

CONCLUSIONS

Average daily water usage measured over a two-year period was 40.9 L/head/d (10.8 gal/head/d). During the winter, drinking accounted for 66% of total usage, while overflow was 32%. During the summer, drinking accounted for 89% of total usage, while leakage through the overflow system was 7%. If all of the overflow water including leakage and tank cleaning were recycled at this feedyard, then 161 600 m^3 (42.7 million gal) of water would be saved per year.

The best fit equation for predicting water usage at the feedyard was:

$$\begin{aligned} \text{DWU} = 39.2 - 0.648\ \text{MAXT} + 0.0421\ \text{MAXT}^2 \\ - 0.0717\ \text{MINRH} \qquad r^2 = 0.60 \qquad (5) \end{aligned}$$

where

DWU = daily water use (L/head/d)
MAXT = maximum daily temperature (°C)
MINRH = minimum daily relative humidity (%)

Options identified for conserving water at feedyards included (1) installing more efficient water troughs, (2) installing electric tank heaters in the existing water troughs, and (3) making improvements to existing systems to reduce leakage. Options for recycling or otherwise using the overflow water included (4) recycling the water back into the drinking water system, (5) using the water for irrigation purposes, (6) using the water for dust and temperature control in sprinkled pens, and (7) using the water in the feedmill.

ACKNOWLEDGMENTS. The authors thank Wrangler Feedyard and Cactus Feeders for their cooperation and assistance with this project, and Mr. Andy Grimes of Canatxx Services Co., Amarillo, Texas, for assistance with the design and cost estimates of the water treatment system.

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