FACTORS INFLUENCING THE AMOUNT OF TIME SPENT BY CATTLE IN STREAMS: IMPLICATIONS FOR TMDL DEVELOPMENT

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ABSTRACT

The amount of time cattle spend standing in streams is one input parameter needed by computer models when total maximum daily load (TMDL) plans are being developed. This input parameter is estimated using professionals' best judgment because experimental data are not available, and estimations are generally inconsistent. The goal of this study was to gain a better estimate of the amount of time cows spend in streams, since this has a significant impact on direct fecal coliform loadings to streams. Significant factors influencing the amount of time cattle spend in streams were identified, and a relationship was developed for predicting the amounts of time cattle spend in streams.

Five farms were studied in southwest Virginia from August 2001 through February 2002. Camera surveillance systems were set up on two beef farms and three dairy heifer operations, and cattle activity in streams was recorded during daylight hours. Climatic data, pasture characteristics, feed characteristics, and farm management practices were collected from each site, and their relationships with the amount of time cattle spend in streams were investigated.

No significant difference (p=0.82) was found between the amount of time beef cattle and dairy heifers spent in streams. Overall, cows spent an average of 10.12 min $day^{-1}cow^{-1}$ standing in streams during the observation period. Throughout the study period from August to February, cows spent the highest amount of time in streams during the month of November (14.3 min $day^{-1}cow^{-1}$).

Feed, climatic, and pasture parameters were found to influence the amount of time cattle spent in streams. These significant parameters were used to develop an empirical equation for predicting cattle presence in streams. This model may not accurately predict the amount of time

spent in streams by cows during warmer summer months, since data was collected during fall and winter months. Other limitations may be encountered when using the model to predict the amount of time lactating dairy cows spend in streams when streams are their sole water source, since they have a much higher water requirement than those cows studied.

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"And we know that in all things God works for the good of those who love him." Romans 8:28

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Chapter 1 : Introduction and Justification

A water body is considered impaired if it does not meet its specified water quality standards. These water quality standards are specified by the state environmental agency in which the water body is located; standards vary depending on the water body's designated use. Section 303(d) of the Clean Water Act requires states to submit a list of the states' waters that do not meet water quality standards for a variety of pollutants, such as fecal coliforms. The list of impaired waters must be submitted to the Environmental Protection Agency (EPA) every two years. In 1998, 175 of Virginia's 883 monitored water bodies were impaired due to fecal coliform and listed on the state's 303(d) list. National regulations require total maximum daily load (TMDL) plans be developed for each water body once they become a part of the 303(d) list. A TMDL is defined as the amount of a particular pollutant that a water body can receive and still meet specified water quality standards.

Computer models such as ANSWERS, GWLF, and HSPF are used to complete TMDL studies. A number of inputs are required for these computer models, including weather data, soil characteristics, topography, animal distribution, and land use. Once these parameters are entered into the model, simulations are run to determine pollutant loadings to water bodies. Parameters can then be changed to evaluate the impact of changing practices on pollutant loadings.

Many input parameters for these computer models are estimated, since scientifically based values are not always available. Oftentimes, the TMDLs are completed by estimating these parameters, and estimates usually vary. One such estimated parameter is the amount of time cattle spend in streams throughout the year. Cattle go to streams to drink and to cool off, often defecating directly in the stream. This activity directly increases fecal coliform loadings to streams, and must be modeled in the TMDL process.

Direct deposition of feces into water bodies is important to water quality because it directly increases fecal coliform loadings to the water body in which it is deposited. Bacteria in feces deposited on land adjacent to streams have the potential to reach streams mainly during rainfall events as a result of overland flow. Although still a concern, bacteria concentrations reaching water bodies from adjacent deposition are lower due to die-off of bacteria; whereas bacteria directly deposited into streams do not have the opportunity for die-off, and therefore have higher concentrations.

Farmers have observed cattle spending more time in streams during the warmer parts of the year, but there is a lack of experimental data in this area to scientifically support these observations. Several recent TMDL studies have recommended cattle be completely fenced from streams to reduce fecal coliform loadings to the impaired water body. Alternative management strategies may be developed, however, if better estimates of cattle presence in streams are available.

Goal and Objectives

The overall goal of this study is to gain a better estimate of the amount of time cattle spend in streams, since this parameter has a significant impact on the amount of fecal coliform directly deposited in streams. Specific objectives for obtaining this goal are as follows:

1. To determine factors that influence the amount of time cattle spend in streams.
2. To develop and evaluate an empirical equation for predicting cattle patterns in streams.

Chapter 2 : Literature Review

Water Quality Impacts

Cattle either standing in, or drinking from streams causes a variety of problems, many of which are related to fecal pollution. Fecal pollution is a great concern since full-grown cattle on pasture defecate approximately 12 times per day (Miner et al., 1992). Waters polluted with fecal material contain bacteria that are the source of many human diseases such as salmonellosis and leptospirosis (Diesch, 1970).

The main concern with cattle in streams, and the focus of this research is fecal coliform deposition in streams, since fecal coliform is used to indicate fecal contamination of waters by livestock. The fecal coliform group has been indicator bacteria for determining the possible contamination of urban water supplies since the early 1900s (Bohn and Buckhouse, 1985). Coliforms themselves may not be harmful, but can be accurately measured and give an indication of the amount of pathogens in a water body resulting from fecal pollution. These bacteria are now being used as indicators of pathogenic contamination of wildland streams. In the past, it was difficult to determine the source of fecal pollution since all warm-blooded animals excrete fecal coliform bacteria. Specific sources of fecal coliform can now, however, be differentiated using a technique called bacterial source tracking (Kern et al., 2000).

Water quality standards for fecal coliform concentrations vary from state to state, and are based on the designated water use. Regulations for shellfish waters in Virginia require that median fecal coliform (FC) concentrations not exceed 14 FC/100 mL (State Water Control Board, 1997). For all other surface waters in Virginia, concentrations cannot surpass 1000 FC/100 mL at any given time. Surface water concentrations must also remain below a geometric mean of 200 FC/100 mL.

Although the subject of many investigations, the behavior of fecal coliform under different conditions is still uncertain. Daily and seasonal fluctuations of fecal coliform concentrations occur, and may be attributed to changes in water temperature, stream stage, and solar radiation (Bohn and Buckhouse, 1985). Edwards et al. (1997) studied fecal coliform concentrations in five streams over a period of three years in Northwest Arkansas and found fecal coliform concentrations to be significantly influenced by season ($p<0.05$). Fecal coliform concentrations were found to be high during summer months, and were affected by stream flow rate; higher concentrations were found during lower flows. Relationship of fecal coliform concentrations and climatic conditions were not evaluated in this study.

Die-off rates of fecal coliform bacteria are also not yet fully understood. Some research suggests fecal coliforms can survive between 13-20 days in soil, leaving a potential for transport to streams with overland flow (VanDonsel et al., 1967), and can survive for up to a year in cow feces (Buckhouse and Gifford, 1976). Fecal coliform bacteria often attach to sediment once deposited in streams, and can survive for months in this state (Sherer et al., 1992). Fecal coliform settles to stream bottoms with the attached sediment, and can be re-suspended as a result of cattle movement in streams. This re-suspension can cause dramatic variation in fecal coliform concentrations (Sherer et al., 1992).

Gary et al. (1983) studied impacts of cattle on a stream in Colorado during May-June 1978 and June 1979. Two pastures (75 and 85 ha) bisected by a stream were used for the study, and study days consisted of 11 hours (700 - 1800 h). Cattle spent approximately 65% of the day within 100 m of the stream, and 5% of the day (33 minutes) in the stream either standing, crossing, or drinking. Observers noted that 6.7-10.5% of the time cattle defecated, they did so directly in the stream, usually shortly after drinking. Fecal coliform levels in the stream with cattle present were 12.5 times greater than levels when no cattle were present.

Tiedemann et al. (1987) studied the effects of grazing management practices on fecal coliform concentrations in streams. Researchers found a significant difference among fecal coliform concentrations with different grazing strategies. Fecal coliform concentrations increased with cattle presence (six times higher than without cattle presence); cattle access to streams contributed more to this increased concentration than cattle stocking density.

The presence of fecal bacteria in streams was studied in two watersheds in Kentucky with relation to agricultural practices (Howell et al., 1995). Sampling revealed that fecal coliform were always present in streams (indicating that not all of the fecal pollution was from cattle), and increased when cattle were present near streams, or after a rainfall event. Fecal coliform concentrations varied between 380-20,000 FC/100 mL when cattle were present in one stream, and stayed below 250 FC/100 mL in another stream without cattle in the nearby pasture. Once cattle were introduced into the pasture near the second stream, however, fecal coliform concentrations remained above 10,000 FC/100 mL, 40 times greater than when cattle were not in the nearby pasture.

Cattle Behavior

Cattle can be confined for either all or part of the day, or can be unconfined and given the opportunity to graze, depending on management practices at a specific farm. These differing practices lead to differences in overall cattle behavior. Cattle divide their time between five major activities: eating, drinking, ruminating, walking, and resting (Squires, 1981). These activities are often interrelated; something that affects one activity impacts at least one other activity. For unconfined grazing cattle, grazing is the most time consuming activity, and is affected by such factors as changes in season, length of day, forage quality, and phases of the moon (Squires, 1981). Rumination depends on both the quality and quantity of food consumed, and so is influenced by grazing patterns. Resting is another important activity for cattle; time spent resting depends on breed, weather, and time spent ruminating and grazing. Cattle spend much of their resting time standing or lying near water sources, and the amount of time cattle spend walking is mainly dependent on water and forage availability (Squires, 1981).

Drinking Habits of Cattle

Water is a necessary component for all life, cattle being no exception. Water intake varies significantly with individual animals under the same conditions, making it difficult to accurately predict the water intake of a single animal (Winchester and Morris, 1956; ARC, 1980). If a large number of animals are studied, however, water intake of the group as a whole can be calculated with increased accuracy.

Cattle fulfill their water requirements through intake of free water, consumption of water contained in feed, and metabolic water created from the oxidation of organic nutrients; the first two methods are the major sources (Church et al., 1974). Water is lost through urination and defecation, with the amount of water lost in urine and feces being approximately equal (feces contains 75-85% water) (Quinton, 1979; Church et al., 1974). Water is also lost through evaporation from cattle's body surface and respiratory tract, with the lower threshold for sweating at approximately $25^{o}C$ (McDowell et al., 1954).

Drinking habits of cattle are extremely complex (Squires, 1981). These habits vary with season, amount and condition of forage available, and other pasture characteristics. Changes in water consumption of dairy cattle have been attributed to changes in dry matter intake (DMI), temperature, humidity, milk production, and diet (Murphy, 1992). The physiological condition of the animal, as well as water availability, quality, and temperature have also been linked to water intake (NRC, 1981). In addition, the efficiency with which a particular cow uses water for its bodily functions varies with breed (Squires, 1981).

Diet

Dietary nutrient concentrations are an important determinant of the amount of water cows drink, particularly protein, salt, and water contents of the feed (ARC, 1980). Water content of feed is an important factor in determining the amount of drinking water cattle need (Church et al., 1974). Water content of feeds can range from 5% for dry grains up to 90% for lush, fresh grasses. MacLusky (1950) attributed 60-70% of water consumed by grazing cows to grass. The amount of dew or precipitation found on grass also contributes to total water intake.

Heifers fed a silage diet consume more total water and urinate more than heifers fed hay due to the increased moisture content of silage (Winchester and Morris, 1956; Waldo et al., 1965). Castle and Thomas (1975) noted that cows fed a silage diet drank fewer times than those fed dried grasses. Rouda et al. (1994) found that increased protein intake decreased overall water consumption in beef cattle, and attributed this result to a decrease in forage intake. Sykes (1955), however, reported that higher amounts of protein in feed increased water consumption in lactating dairy cows.

Salt intake also affects water consumption (Woodford et al., 1985). In lactating dairy cows, adding 2% sodium chloride to their base diet increased water consumption 27%, while DMI remained almost constant. The addition of sodium bicarbonate to the diet increased water consumption approximately 16%. Similarly, Murphy et al. (1983) showed that water consumption increased by 50±23 mL with each additional gram of sodium fed.

Nocek and Braund (1985) conducted research on the effect of feeding frequency on water intake of housed lactating dairy cows, and discovered that feeding frequency did not significantly influence total mean daily water intake, although a small effect was noted. A slight increase in water intake was observed with increased feeding frequency; when fed the same diet, cows fed eight times a day drank the most water (76.6 L/d), while cows fed only once per day drank the least amount of water (67.9 L/d). A correlation was reported between hourly feed intake and voluntary hourly water intake.

Dry Matter Intake

Dry matter intake is closely related to an animal's size, production level, physiological condition, and water intake. Castle and Thomas (1975) found a significant positive relationship between free water intake of dairy cows and dry matter content of ration; cows drank more water when fed drier feeds. MacLusky (1959), Paquay et al. (1970), and Stockdale and King (1983) also noted a positive correlation between water intake of dairy cows and dry matter content of diet, as well as between water intake and DMI of dairy cows on pasture. Dairy cattle consume an average of 2-4 kg water for every kg dry matter consumed (Kay and Hobson, 1963), and a 4.54 kg increase in DMI resulted in an increase in water consumption of dairy cows from 7.57 to 9.46 L/day in one study (Woodford et al., 1985).

Physiological Condition

Physiological condition and growth state of animals impact both feed and water requirements (ARC, 1980). Lactating or pregnant cows, dry cows, and growing calves have different requirements than older animals grown and fattened for meat. Young calves often consume more water per unit of body weight than older cows, and dry cows in their last four months of pregnancy drink about 30% more than when they are dry without calf (ARC, 1965). Increases in water consumption at this stage can be attributed in part to an increased DMI, which results from an increase in overall feed intake that is necessary to fulfill nutritional requirements (Winchester and Morris, 1956). Results from a study conducted on grazing beef cattle in south-central New Mexico showed that lactating cows drank 24% more water than non-lactating cows, with non-lactating cows drinking an average of 50 L/day (Rouda et al., 1994).

Social rank of a herd can also affect feeding and drinking patterns (Anderson et al., 1984). The amount of water drank by dominant and submissive cows are approximately equal; however, submissive cows usually consume water in more frequent intervals, consuming a smaller amount at each drinking bout.

Milk Production

A large portion of milk produced by cows consists of water, approximately 87% by weight (Leitch and Thompson, 1944; Woodford et al., 1985; Murphy, 1992). As a result, lactating cows drink 1.5-2.2 times the amount drunk by a dry cow; water intake for stalled lactating cows is about 0.87 kg water/ kg milk produced (Winchester and Morris 1956). In addition to water needed for body maintenance, lactating dairy cows need approximately 3.79 L of water for every 4.35 L of milk produced (1 kg/0.87 kg milk produced) (Woodford et al., 1985). Paquay et al. (1970) concluded that the amount of milk produced per day by dairy cows did not influence total water intake, but that moisture content of diet and DMI provided sufficient water for milk production.

Dado and Allen (1994) noted a positive correlation between milk yield and water intake in their study of six multiparous (in their second or greater lactation) and six primiparous (in their first lactation) stalled lactating Holstein cows. Multiparous cows drank an average of 89.5 L/day (2.4 kg/kg milk produced), considerably more than the 63.2 L/day (2.2 kg/kg milk produced) that primiparous cows drank. This difference in water intake was correlated with a difference in milk yield between the two groups; multiparous yielded an average of 37.5 kg/day and primiparous yielded an average of 28.7 kg/day. Multiparous cows were larger in size and had larger rumens, which may have partly contributed to increased water intake and milk productivity.

Although many comparisons are often made between housed and grazed cattle, MacLusky (1959) and Stockdale and King (1983) do not believe equations predicting water intake of housed cows can be applied to those on pasture, primarily due to differences in environment and diet. Past research has shown that approximately 1 kg of water per 1 kg of milk produced is necessary for grazing dairy cows (MacLusky, 1959). This differs from previously discussed results of housed dairy cows (Winchester and Morris 1956; Dado and Allen, 1994). Milk-producing cows on pasture require 9.5 L of water for everyday maintenance, which can also vary with size of cow. Differences in reported water requirements for dairy cows in studies previously discussed might also be attributed to differences in size of animals or diet.

Temperature/Seasonal Variations

Water requirements of cattle change both daily and seasonally (Squires, 1981). Many times an increase in water intake is noted with increased ambient air temperatures, such as during warmer summer months. In arid regions, cattle need at least one drink per day during warmer parts of the year, while they may go three days without drinking during the winter months (Squires, 1981). Water needs of individual animals vary more at temperatures greater than 30^{o}C because animal behavior and respiration rate vary more at higher temperatures (NRC, 1981).

Rouda et al. (1994) discovered a negative correlation, however, between water intake and mean maximum daily temperature for temperatures at or above 30°C when studying lactating and non-lactating beef cattle in south-central New Mexico under grazing management. This negative correlation may have been the result of an unusually high amount of rain during the study period (10.1 cm in two months), and cattle may have drunk water from puddles as a result of rainfall events. Average daily temperatures during this study did not influence water intake at temperature ranges between 14-28°C (Rouda et al., 1994).

Wilson (1961) determined that water consumption increased more during warmer months in hot, arid climates, sometimes increasing by up to 72% (ARC, 1980). Water consumption of mature, lactating Holstein cows increases approximately 6.06 L/day for every 5.6°C change in environment between 4.4 – 29.4 °C (Woodford et al., 1985). Murphy et al. (1983) found a positive correlation between water intake and temperature with multiparous Holstien cows consuming 1.20 kg more water per degree change in minimum temperature.

Mullick et al. (1952) studied the seasonality of water intake of grazing beef cattle drinking from a watering trough in central northern India. At this location the average spring, summer, fall, and winter temperatures averaged approximately 30, 36.7, 31.1, and 17.8°C, respectively, and relative humidity varied from 40-90%. Water intake was lowest during winter months, and increased during warmer weather. Average water consumption during spring, summer, fall, and winter was 13.5, 15.1, 11.4, and 9.5 kg/day, respectively.

Humidity

Humidity does not have a strong effect on water consumption at low to moderate temperatures (Ragsdale et al., 1953). At higher temperatures, however, water intake decreases with increasing humidity, while frequency of drinking increases. Lower DMI could contribute in part to decreased water consumption in these situations. Rouda et al. (1994) found water intake of lactating and non-lactating beef cattle on pasture to be positively (but weakly) correlated with relative humidity. Data during this study was collected during May-July in south-central New Mexico where relative humidity ranged between 15-86%. Castle and Thomas (1975) did not find a significant correlation between water intake of dairy cows and relative humidity in the United Kingdom, where there was an average temperature of 8.2°C and relative humidity of

84.8% during their six-month study period. Type of cow and diet may have combined to influence results of the previously discussed studies.

Pasture Characteristics

Landscape and pasture characteristics influence cattle behavior, which in turn can affect water consumption. Quality and availability of forage in pastures affect cattle behavior and influence watering routines (Squires, 1981). Valentine (1947) suggests that pasture size, shape, and distance to water affect cattle behavior in terms of grazing patterns, and that the amount of vegetation alone does not determine grazing capacities. The location and amount of shade is another important factor affecting cattle behavior (Buffington et al., 1983).

Researchers have credited cattle presence in streams to the quality of forage and their need for water (Gary et al., 1983). Cows consuming forage with higher moisture contents consume less water directly. Water consumption depends on water availability (Paquay et al., 1970). In dry tropical climates, water consumption decreases with increased distance to water sources (Castle, 1972). Senft et al. (1985) determined that proximity to water (1/distance) was positively correlated with grazing distribution during growing and dormant seasons for pasture. Researchers have also noted concentrated grazing of forage surrounding watering locations. Smith et al. (1992) concluded that cattle more often selected forage near streams as opposed to upland forage, and attributed this to more lush forage around streambeds. Valentine (1947) concluded that grazing capacities vary if pastures contain the same type and quantity of forage and are the same size and shape, but watering locations are different.

Hart et al. (1993) studied eleven pastures in Wyoming to determine the effect of pasture size on beef cattle grazing behavior. During the study, the maximum distance cattle had to travel for water was 5 km in a large pasture (207 ha), and 1-1.6 km in the smaller pastures (24 ha on average). In the large pasture, cattle ate more forage around the water source, and made fewer trips to get water when grazing farther away from the water source. Cattle did not go to the water source on cool, damp days at all, and overall, spent approximately 93% of their time grazing in all pastures (Hart et al., 1993).

During a 4½ -year study, Hodder et al. (1978) determined drinking habits of beef cattle in arid zones to be dependent on climatic conditions and forage location. Researchers categorized three main watering periods of cattle as midmorning, after daybreak grazing, and in the late afternoon before evening grazing. Cattle sometimes had to travel 15-20 km from watering points to find adequate forage.

Shade

The amount of shade in pastures is an important factor contributing to cattle productivity. Shade protects cattle from direct solar radiation, reduces the radiant heat load of a cow by more than 30%, decreasing the chance for heat stress, and improving cattle performance. Cattle often congregate in shady areas during periods of high temperatures (Squires, 1981).

Mader et al. (1999) studied the performance of feedlot cattle in relation to shade, and determined that shade temporarily improved performance, an effect enhanced with increasing heat load. McDaniel and Roark (1956) investigated the performance of cattle under different shade conditions over four years in western Louisiana. Four pastures were studied with plentiful natural shade, sparse natural shade, artificial shade, and no shade. Cows without any shade drank more frequently than those with shade, and weight gains were higher in pastures where cows had access to natural shade. The amount of time cattle spent grazing was influenced by the amount of shade in pastures, those with plentiful natural shade spent the most time grazing.

Off-stream Watering Sources

The presence of off-stream watering sources is considered a best management practice (BMP) to effectively decrease cattle presence in streams without the use of fencing. Sheffield et al. (1997) collected field data before and after adding alternative watering sources on two commercial cow-calf operations in southwest Virginia. After the installation of off-stream watering sources (spring-fed troughs), time spent drinking from streams dropped from 6.7 to 0.7 min $day^{-1}cow^{-1}$, an 89% reduction. A drop in overall cattle presence in the stream from 12.7 to 6.2 min $day^{-1}cow^{-1}$ was recorded after the installation of watering troughs, and a 51% reduction of cattle in streams (Sheffield et al., 1997). Cattle drank from troughs 92% of the time they drank water.

Clawson (1993) experienced comparable results to Sheffield et al. (1997) when installing off-stream watering sources with cattle presence in streams dropping from 4.7 to 0.9 min. Miner et al. (1992) also experienced similar results studying two groups of dairy cows in Oregon under winter feeding conditions: one with sole access to a creek, and the other with access to both a water trough and creek. The water trough effectively reduced cattle presence in streams by 99%

during the part of the day when thirst tended to drive cows to the stream (following feeding), but this reduction dropped to 80% for the rest of the day as some cows still tended to loaf in the stream.

Fescue Toxicity

Fescue toxicity can alter cattle behavior, making it an issue to be addressed when discussing cattle behavior. Tall fescue (*Festuca arundinacea*) is a common forage for cattle across the United States, being grown on more than 35 million acres, and supporting over 8.5 million beef cattle (Ball et al., 1996). Tall fescue is a cool season grass that is easily grown with a long grazing season, and has high crude protein, dry matter, and mineral contents that can lead to good animal performance. Performance is reduced, however, when fescue is infected with the fungal endophyte, *Acremonium coenophialum,* as is the case in Virginia (O. Abaye, personal communication, Virginia Tech, 10 July 2001). Problems with reproduction, reduced weight gain, and gangrenous conditions of tails and feet may occur when animals consume large quantities of endophyte-infected fescue (Ball et al., 1996).

Cattle can be affected by consuming endophyte-infected fescue in three major ways: fescue foot, bovine fat necrosis, and fescue toxicity (summer slump) (Stuedemann and Hoveland, 1988; Ball et al., 1996). Fescue foot occurs mostly during the winter in parts of the upper south, and is characterized by rough hair, elevated body temperatures, and gangrenous conditions of feet and/or tails. Bovine fat necrosis causes hard masses of fat in the adipose tissue surrounding the intestine, resulting in digestive and calving problems. Bovine fat necrosis has also been related to high applications of nitrogen (N) fertilizer, especially via poultry litter. Fescue toxicosis, or summer slump, is the third syndrome associated with endophyte-infected tall fescue. This syndrome is characterized by poor animal performance during summer months, reduced weight gains, intolerance to heat, excessive salivation, nervousness, elevated body temperature, failure to shed the winter coat, lower milk production, and decreased conception rate (Stuedemann and Hoveland, 1988; Ball et al., 1996).

Drinking Time

Cattle are more likely to drink at certain times of the day due to daily climatic and feeding factors. Milking schedules of dairy cows also play an important role in determining drinking schedules. In a November-April study of 14 different dairy herds located across

England and Wales, Castle and Thomas (1975) observed relationships between different rations and water intakes. These herds consisted of 580 dairy cattle total, and were managed for typical conditions in the United Kingdom. The average temperature during the study period was 8.2^{o}C, and the average relative humidity was 84.8%. Average daily water intake was found to be 49.9 kg/cow, and researchers observed that 33.9% of this amount was drunk between 0900-1500 h, 40% between 1500-2100 h, and 26.1% of water intake occurred from 2100-0900 h. The highest water demand occurred in the early evening 1-3 hours after milking. Drinking bouts ranged from 2-7.8 min day^{-1}cow^{-1}, with drinking rates from 4.5-14.9 kg/min. Rouda et al. (1994) measured the length of drinking time for their 67 lactating and non-lactating cattle on pasture and found that 77% of cattle drinking events lasted between 2-4 minutes during May-July.

Nocek and Braund (1985) found that cows in their first lactation tended to consume water and feed alternatively if given the chance, and that peak water intake was linked to peak DMI. The average length of time beef cattle spent drinking in central Australia under grazing conditions were 4.5, 3.6, 2.6, and 3.4 min/day during the summer, fall, winter, and spring, respectively (Squires, 1981).

Cattle Monitoring

An essential part of any research project is data collection. In behavior-based research, it is imperative to monitor animals without interrupting their everyday pattern, which can be challenging. Many monitoring methods have been used throughout the years including direct observation, video surveillance systems, remote sensing, radio frequency technology, and global positioning systems (GPS).

Most cattle monitoring in the past has been through direct observation, which has its limitations. Its biggest drawback is that it is labor intensive, requiring someone to be in the field with the cattle recording their activities at a set interval (generally every 5-10 minutes). A decrease in accuracy may also occur since observations are not usually made during the night when activities can be quite different from those during daylight hours. Also, there is the potential for the observer to frighten cattle and unknowingly alter their behavior patterns.

A more expensive alternative to direct observation of animals is to use GPS. GPS is a satellite-based system that has evolved into an accurate location information system. Lightweight GPS collars that do not interfere with an animal’s behavior can be bought or manufactured. A study involving the fitting of sheep with lightweight GPS collars indicated that their lifestyle was unaffected by the presence of the collar (Hulbert et al., 1998). Turner et al. (2000) also used GPS collars weighing less than 1 kg to monitor and track cattle behavior on pasture with success.

A less expensive approach to monitoring cattle behavior involves the use of camera systems. Vasilatos and Wangsness (1980) used a movie camera modified for single frame and fitted with a control timer to monitor feeding behavior of lactating dairy cows. After validation, Vasilatos and Wangsness determined the use of time-lapse photography to be sufficient for studying cattle feeding behavior. Anderson et al. (1984) also effectively used video monitoring equipment to study drinking behavior of stalled dairy cows.

Improved technology is leading to an increased use of remote sensing in the dairy industry (Wheeler and Graham, 1986). Some applications include the monitoring of parameters associated with milk production, cattle identification, and cattle tracking. Considerable work has been done with individualized automatic feeding and amount of cattle movement in field situations, but not identifying animal location. InfoRay Technologies, Ltd. has developed new technology that combines those previously available applications (amount of movement, automatic feeding, etc.) with the ability to retrieve a cow's 3D position (Halachmi and Braiman, 2000). Pinchak et al. (1991) also used radio telemetry collars to study the distribution of beef cattle on range with success.

Summary

Cattle presence in streams causes environmental concerns due to its impact on direct fecal coliform loading to streams. Farmers and researchers, alike, have noted that cows often defecate while standing in streams, contributing directly to levels of fecal bacteria in streams. Two main reasons cattle enter streams are to drink and to cool themselves during warmer periods.

Many factors affect drinking habits of cattle, making these habits highly variable. Diet plays an important role in a cow's water requirement. The more water contained in feed, the less cattle need to drink to fulfill their water requirement. Dry matter content in feed varies with type of feed (hay, silage, grain, grass) and also time of year (with respect to grasses). Physiological condition of cows impacts water requirements. Lactating cows consume more water than dry cows since they are producing milk, which is approximately 87% water.

Scientifically based estimates of the amount of time cows spend in streams are unavailable. Limited research has been conducted on the relationships between temperature, humidity, season and presence of cattle in streams. Water intakes increase with increasing temperatures, and increasing temperatures also drive cattle to streams for cooling purposes. There are a number of pasture characteristics that affect cattle presence in streams, such as pasture quality and pasture shape. The amount and location of shade in pastures affects where cattle loaf the majority of the time, and distance to water affects how often cattle visit watering sites.

Providing alternative off-stream watering sources is an effective measure for decreasing the amount of time cattle spend in streams, but does not reduce time spent in streams for cooling purposes. Additional research is needed to relate cattle presence in streams with climatic, physical, and topographic factors so cattle presence in streams can be more accurately predicted.

Chapter 3 : Methodology

Experimental Design

The study took place on five different farms in southwest Virginia from August 2001 through February 2002. The starting surveillance dates and observation periods varied at each site because several cooperating farmers practiced rotational grazing. Therefore, cattle were not always present in pastures with stream access throughout the year on those farms. Dairy heifers were monitored on three sites and beef cattle were monitored on the remaining two sites. Dairy heifers are defined as those female cows that have not yet borne any calves, and are generally under two years of age; they are not lactating.

Streams flowing through the study pastures provided the only source of water for cows at each study site. Cattle were not confined on any farm. The starting and ending study dates, number of cows on each farm, farm location, and general animal description for each farm are presented in Table 3-1. An animal-month is the number of months (based on a 30-day month) of data reviewed for each site calculated on a per cow basis. Detailed animal descriptions are found under each farm description.

Table 3-1: Description of each study site.

Farm	Starting Date	Ending Date	# Head	Type	Location	Animal* Month
A	8/15/01	11/12/01	24	Dairy heifers	Montgomery Co.	48.8
B	10/31/01	11/6/01	7	Dairy heifers	Montgomery Co.	1.63
B	11/6/01	1/2/02	13	Beef cows, dairy heifers, dairy calves	Montgomery Co.	28.17
B	1/2/02	2/28/02	6	Dairy heifers	Montgomery Co.	10.8
C	11/17/01	2/28/02	26	Dairy heifers	Washington Co.	52
D	11/20/01	1/6/02	52	Beef cow/calf pairs	Montgomery Co.	41.6
D	1/6/02	1/12/02	16	Beef cows	Montgomery Co.	2.67
D	1/12/02	1/23/02	8	Beef cows	Montgomery Co.	2.4
D	1/23/02	1/31/02	3	Beef cows	Montgomery Co.	0.6
E	11/26/01	1/30/02	52	Beef cow/calf pairs	Montgomery Co.	41.6

Surveillance Systems

Outdoor video surveillance systems were installed at each study site. Up to four different surveillance cameras were installed at each site as needed, depending on the length of stream segment flowing through each study section. The surveillance cameras on each farm were connected to a multiplexer box, which was then connected to a time-lapse VCR. The multiplexer box switched views among cameras every 30-60 seconds, and the time-lapse video camera recorder (VCR) was programmed to take a snapshot of each camera view every 30-60 seconds. The snapshot taken of each view was video footage that lasted approximately 3-4 seconds.

Table 3-2 displays the number of cameras at each study site; longer stream segments required more cameras for stream observation. As previously mentioned, the multiplexer and VCR at each site controlled the length of time of one camera cycle, which also varied among farms (Table 3-2). A camera cycle refers to the amount of time from the snapshot taken of one camera view to the next snapshot taken of the same camera view (after cycling through other cameras).

Table 3-2: Number of cameras at each study site.

Site	Number of Cameras	Camera Cycle Length
Farm A	4	2 min
Farm B	2	45 sec
Farm C	1	45 sec
Farm D	3	1.5 min
Farm E – 1*	4	45 sec
Farm E – 2*	1	45 sec

*Farm E was subdivided into two sections, which will be discussed under the Farm E description.

Four cameras were necessary to observe the stream segment at Farm A. A two-minute interval existed between cameras. Some overlapping of cameras did occur, and was accounted for when interpreting videotapes; cows were not counted twice. Farm B had two cameras, each camera taking a snapshot every 45 seconds. There was no overlapping of cameras at Farm B. Only one camera was needed at Farm C, snapshots of the same view were taken every 45 seconds. The three cameras installed at Farm D switched views every 30 seconds, for a complete camera cycle time of 1.5 minutes. Some camera overlap occurred at Farm D, but was accounted for during interpretation. Four cameras were used during the first half of the study at Farm E. These four cameras were connected to a multiplexer box that allowed snapshots from all four cameras to record on one screen simultaneously. The screen was divided into four views, and camera views did not cycle, facilitating interpretation. Only one camera was needed during the second half of the study at Farm E. This camera took snapshots of the stream every 45 seconds.

Equipment necessary for recording at night was beyond the project budget; therefore, streams were only videotaped during daylight hours. Implications of this procedure are discussed at the beginning of the results and discussion section. The recording range changed throughout the study period due to changes in daylight hours; recording ranges are found in Table 3-3.

Table 3-3: Monthly range of videotaped hours for the study period.

Month	Time Range
August	0600 – 2100 h
September	0630 – 2030 h
October	0630 – 1945 h
November	0630 – 1815 h
December	0700 – 1800 h
January	0700 – 1830 h
February	0645 – 1845 h

All video surveillance systems required power. The systems for Farm B and Farm C were located on farms where electrical outlets were nearby to provide power to the surveillance systems. Each system at the remaining three farms (Farms A, D, E) was powered by a 75 W Siemens (Model #SP75) solar panel and two 12 V marine lead acid batteries connected in parallel. Batteries were changed every four to five days depending on the power collected by the solar panels, which was determined from the length of daylight and intensity of the sun.

Climatic Data

Climatic data were obtained for the study from nearby weather stations. Climatic data for the Montgomery County farms were obtained from the Blacksburg Division of the National

Weather Service located in Blacksburg, Virginia. A weather station on the Emory and Henry College campus located in Washington County, Virginia provided weather data for the farm located in Washington County. Variables obtained on a daily basis were mean temperature, maximum temperature, minimum temperature, precipitation, average wind speed, and average relative humidity. Monthly averages for climatic data collected during the study period for Blacksburg and Washington County are presented in Figure 3-1- Figure 3-6.

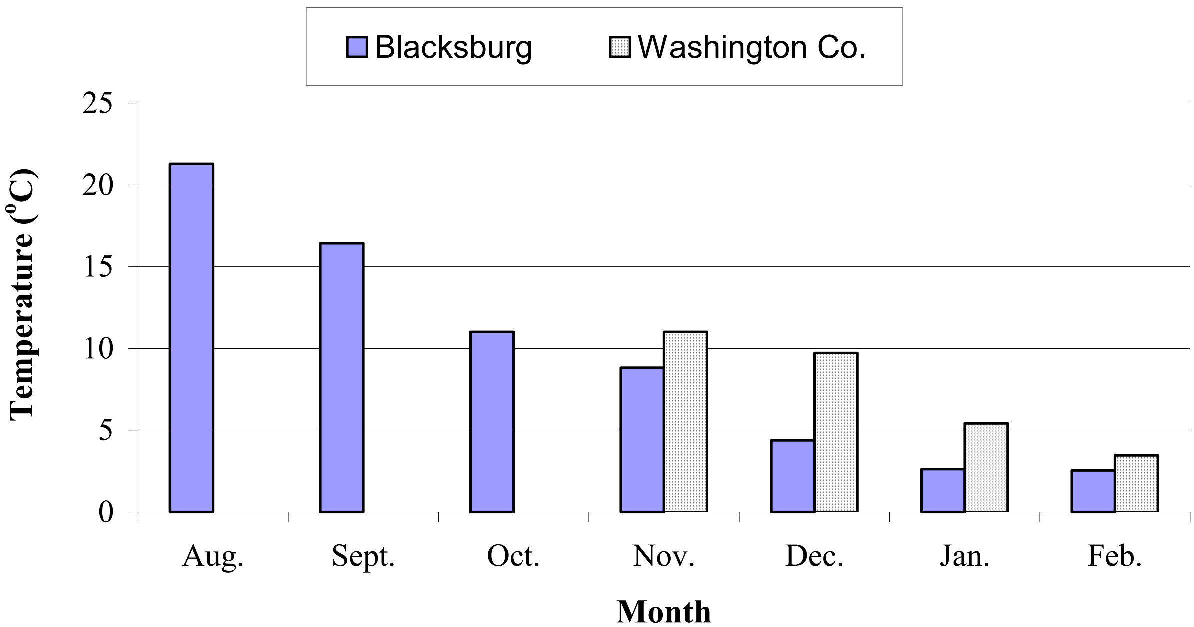

Figure 3-1: Monthly summary of average daily temperatures during the study period.

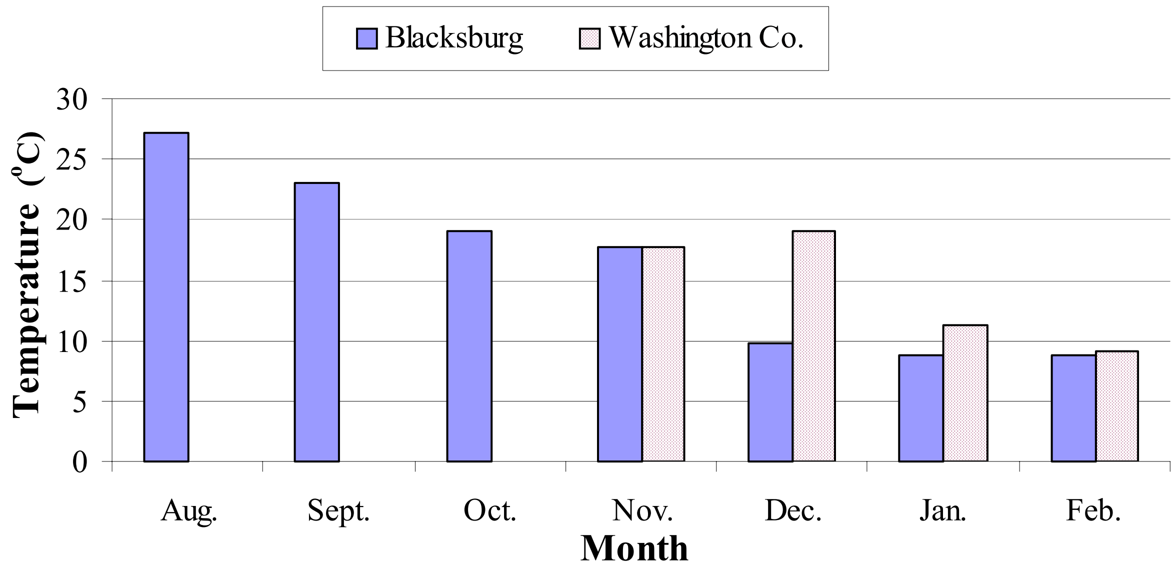

Figure 3-2: Monthly summary of maximum daily temperatures during the study period.

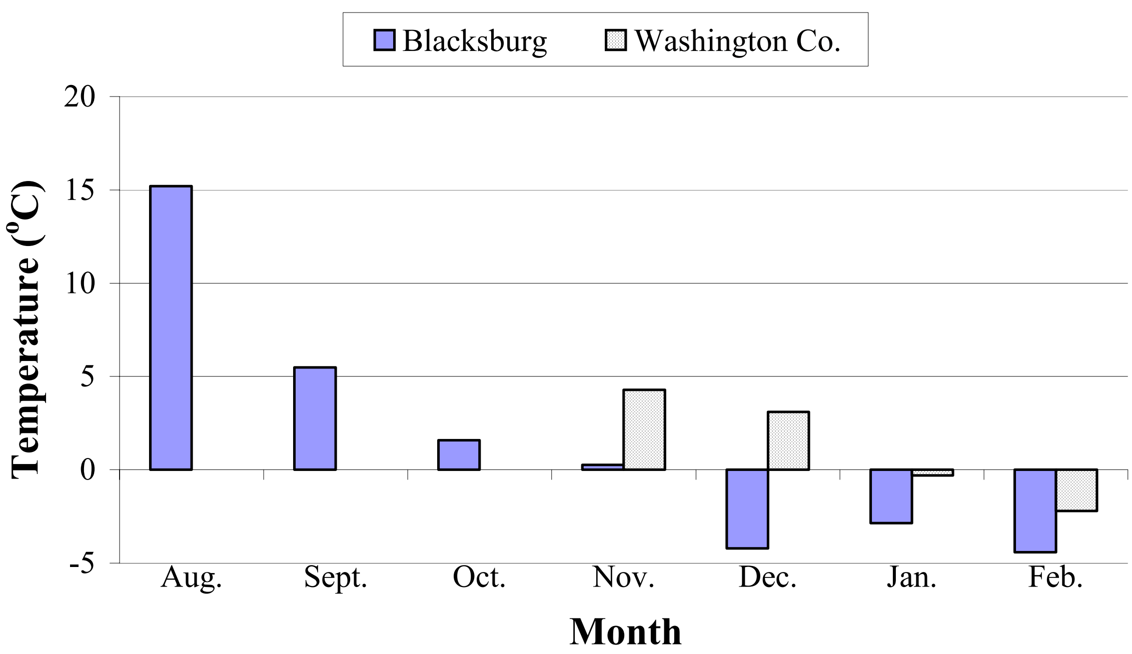

Figure 3-3: Monthly summary of minimum daily temperatures for the study period.

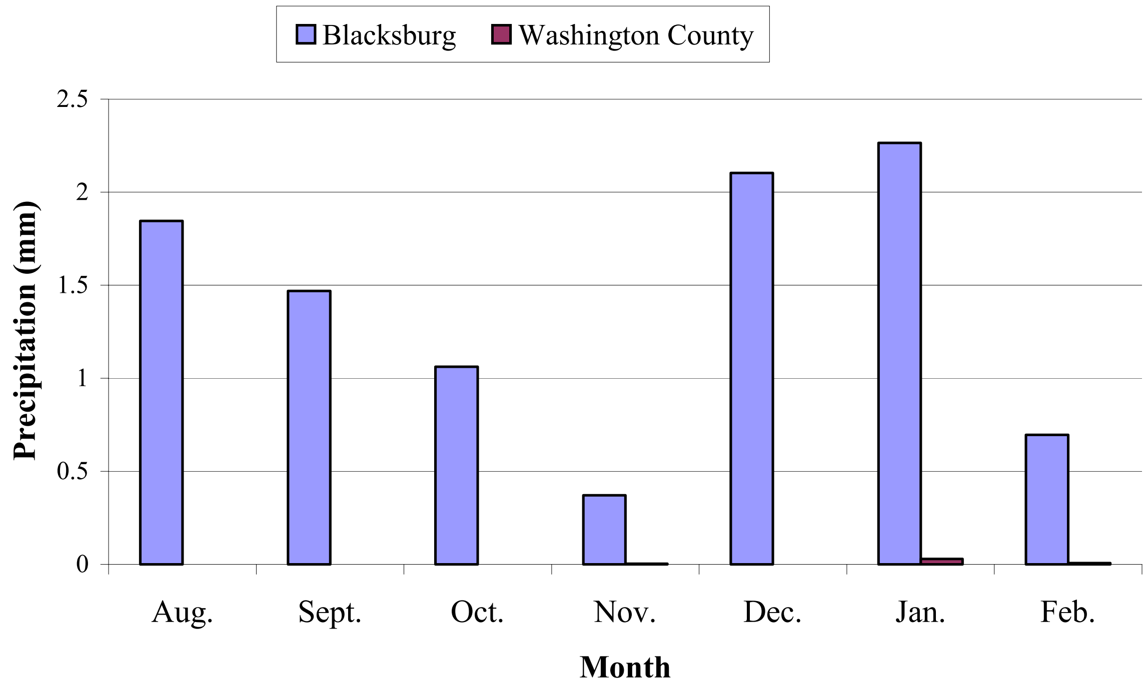

Figure 3-4: Monthly summary of precipitation during the study period.

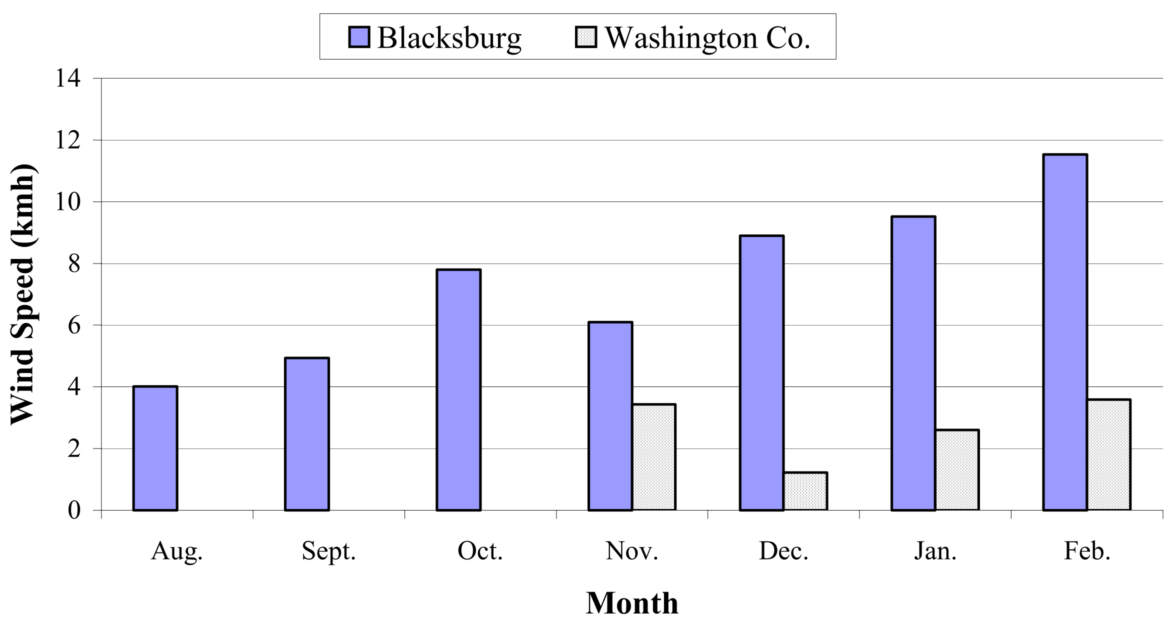

Figure 3-5: Monthly summary of average daily wind speed for the study period.

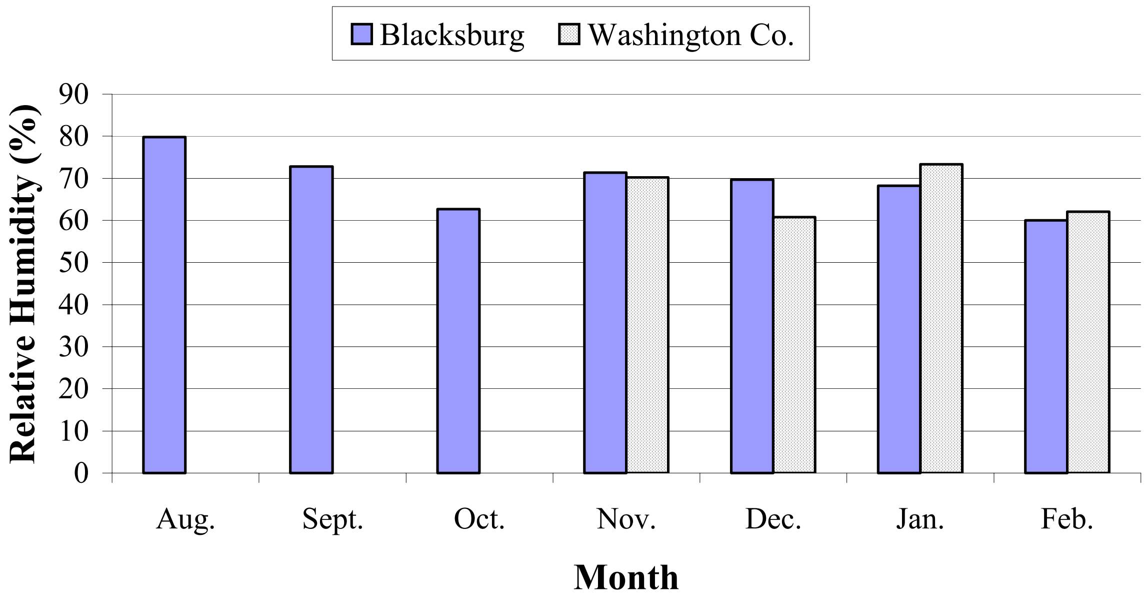

Figure 3-6: Monthly summary for average daily relative humidity during the study period.

Historical climatic data were also obtained from weather stations in Washington County and Montgomery County from the National Climatic Data Center (Tables 3-4 and 3-5). This data was used to compare climatic conditions during the study to climatic conditions from past years.

Table 3-4: Historical temperature data (°C) for Washington and Montgomery Counties.

Month	Max[1]	Min[1]	Mean[1]	Max[2]	Min[2]	Mean[2]
Jan	6.1	-5.6	0.3	5.1	-6.3	-0.6
Feb	8.8	-4.1	2.4	7.1	-5.5	0.8
March	14.2	-0.2	7	11.8	-1.4	5.2
April	19.2	4.1	11.6	17.2	2.8	10
May	23.6	9.1	16.3	21.9	7.9	14.9
June	27.4	13.7	20.1	25.9	12.9	19.4
July	29.4	15.8	22.7	28.1	15.4	21.7
Aug	28.7	15.1	21.9	27.4	14.3	20.9
Sept	25.7	11.4	18.6	24.1	10.4	17.2
Oct	20	4.4	12.2	18.5	3.3	10.9
Nov	13.9	0.2	7.1	12.8	-0.8	6.0
Dec	8.3	-3.9	2.2	7.2	-4.9	1.2

[1]Washington County
[2]Montgomery County

Table 3-5: Historical precipitation data (cm) for Washington and Montgomery Counties.

Month	Precipitation[1]	Precipitation[2]
Jan	10.4	8.6
Feb	9.8	7.7
March	11.4	9.7
April	9.5	9.7
May	12.5	11.2
June	10.4	8.4
July	12.2	10.6
Aug	9.2	9.3
Sept	9.2	8.6
Oct	7.0	8.1
Nov	8.5	7.5
Dec	10.3	7.3

[1]Washington County
[2]Montgomery County

Collection of Pasture Characteristics

In order to better compare different sites, a representative stream cross section from each study site was surveyed. Average depth and flow rate of streams at each site were measured during the last week of March using a Marsh McBirney flowmeter. Only one depth and one flow measurement was taken at each site; multiple readings were not taken over the course of time.

A global positioning system (GPS) was used to collect latitudes, longitudes, and elevations of field boundaries for each site. Aerial photographs were obtained and georeferenced using collected GPS data and digital raster graphic (DRG) topographic maps. Total shaded area and shaded stream area of each pasture were determined using overhead aerial photography and ArcView Geographic Information Systems (GIS) software. Using the georeferenced aerial photographs in ArcView, polygons were drawn around all tree canopies located within the study pasture. ArcView then calculated the area of the polygons; thereby calculating shaded area in the pasture.

Distances from feeding spots to streams, as well as stream length were acquired for each site using aerial photographs and ArcView. Line segments were constructed on aerial photographs in ArcView from feeding locations to closest stream access points for each site. The length of those segments was then calculated by ArcView to give total feed-to-stream distances. Stream length was collected using the GPS and interpreted in ArcView. Total pasture acreage was obtained from farmers. Farm pasture characteristics are presented in Table 3-6.

Table 3-6: Pasture characteristics of each study site.

	PA[1]	SL[2]	TS[3]	TSPA[4]	DCS[5]	PASS[6]	PLSS[7]	DHW[8]	DGW[9]	LTW[10]	SDEN[11]
	(ha)	(m)	(ha)	(ha/ha)	(m)	(%)	(%)	(m)	(m)	(m/m)	animal/ha
Farm A	17.28	108	7.09	0.410	0.0	2.06	100	none	803	1.95	1.39
Farm B	5.99	121	2.14	0.357	0.0	0.95	7.4	95	279	2.22	1.53
Farm C	6.81	16.2	0.31	0.046	38.0	0	0	8	52.4	2	3.81
Farm D	6.11	384	.002	0.0002	16.0	0	0	135	304	0.95	5.41
Farm E -1	9.71	670	2.11	0.218	0.0	34.3	50.3	none	none	2.22	5.35
Farm E-2	3.8	16	0.101	0.026	0.0	0.48	100	none	none	4.12	13.66

[1]Pasture area
[2]Stream length
[3]Total shaded area in the pasture
[4]Ratio of total shaded pasture area to total pasture area
[5]Distance from stream to closest shade
[6]Percent of total shaded area that is located around the stream
[7]Percent of total stream length that is shaded
[8]Distance from hay feeding location to stream
[9]Distance from grain feeding location to stream
[10]Length to width ratio of the pasture
[11]Average pasture stocking density (note: stocking densities varied on Farm B and Farm D with regard to date – see farm descriptions)

Forage Sampling

Representative pasture samples were collected once a month at each site. For each sample taken, a 1-m^2 quadrat was randomly thrown six times throughout the field and hand-held plant clippers were used to clip grass inside the quadrat. Grass was clipped 2.5-5.1 cm above the ground. For each farm, all six samples were composited and placed in an airtight bag. Samples were analyzed for dry matter content, crude protein (AOAC, 1984), neutral detergent fiber (NDF) (VanSoest et al., 1991), acid detergent fiber (ADF) (VanSoest, 1963; Goering and VanSoest, 1970; VanSoest, 1973), and total digestible nutrients (TDN) (Virginia Tech Forage Testing Lab, Blacksburg, VA).

Feed (grain, TMR, corn silage ration) was sampled only once at each site on which it was fed, since its nutrient components did not vary. For each site, four handfuls of feed were randomly taken from feed troughs when cattle were being fed and placed in airtight bags for analysis. Feed samples were also analyzed for the aforementioned nutrient components (Virginia Tech Forage Testing Lab, Blacksburg, VA).

Cows were fed round-bales on farms where hay was fed. Hay was sampled once at each site on which it was fed for the study period. Four random handfuls were taken from the inside of each round bale and composited to get a representative sample. Samples were stored in an airtight bag and analyzed for the five previously mentioned nutrient components (Virginia Tech Forage Testing Lab, Blacksburg, VA).

Farm Management Practices

Additional farm management practices and cattle data were acquired from each farmer. These data included feeding schedules and amounts, breed, age, average weight, and weight gain estimation for animals on each field.

Site Descriptions

Names and specific locations of farms used for the study are not given in order to protect the farmers' privacy. Cattle were not confined on any farm, and instead spent all of their time in pastures.

Farm A

Farm A is a dairy located in Montgomery County, Virginia. The study period for this farm was from 8/15/01-11/12/01 due to rotational grazing. Twenty-four bred heifers, 12 Holsteins and 12 Jerseys, were studied. All heifers were due to calve between 12/15/01 and 3/15/02. Average weight at the end of the study was 499 kg for Holsteins, and 363 kg for Jerseys.

An aerial photograph of Farm A with pasture boundaries outlined is shown in Figure 3-7. A spring-fed stream is located in one corner of the 17.3- ha pasture, and provides the only source of water for cows in the pasture. Since the stream is located in one corner of the pasture, cows must make a special trip there in order to drink. There is not a significant amount of grazing land on the far side of the stream, so it is not necessary for cattle to cross the stream. Cows do not need to cross the stream to get to other sections of the pasture as they did at other farms.

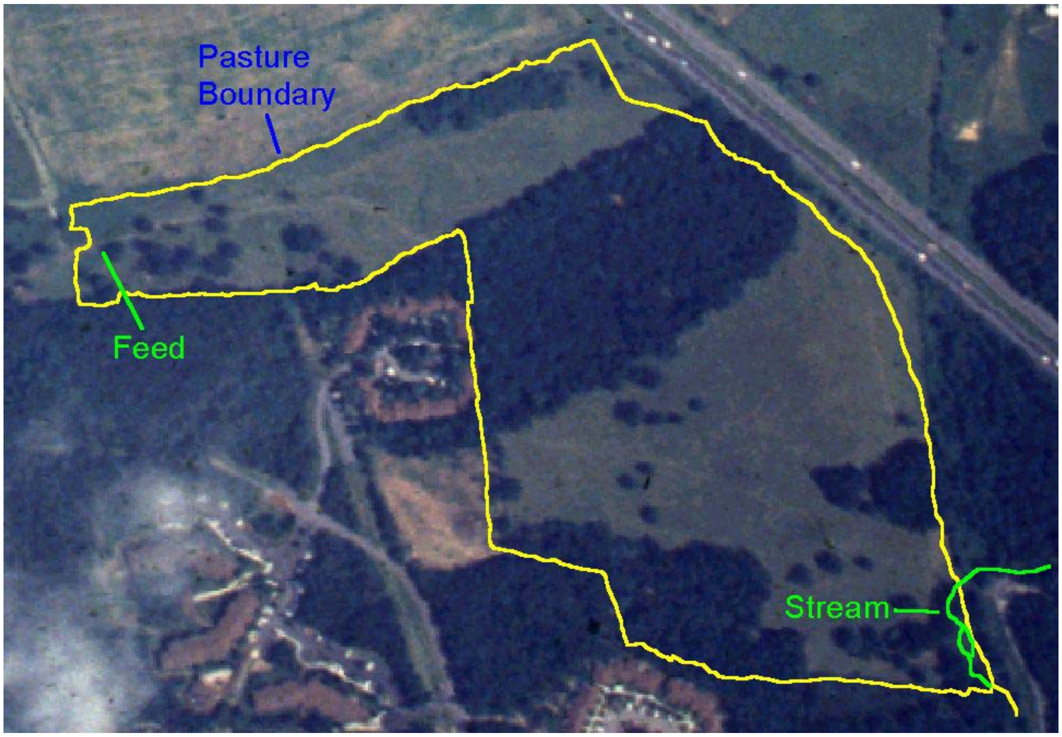

Figure 3-7: Map of Farm A.

The stream at Farm A is approximately 1.32 m wide and 108 m in length, with an average depth of 0.10 m and flowrate of 0.045 m/s. The stream bottom is characterized by fine sediment. The banks of the stream at Farm A were not very steep throughout, allowing cows to have almost complete access to the stream. Figure 3-8 and Figure 3-9 show sections of the stream at Farm A.

Figure 3-8: Stream section at Farm A.

Figure 3-9: Stream section at Farm A.

A significant amount of shaded area is found throughout the pasture, with 7.09 ha total shaded area. A small hardwood forest located away from the stream constitutes much of this shaded area; however, two percent of the total shaded area does surround the stream. Trees shade the entire length of the stream for most of the day.

During the study, cows were fed 1.36 kg/day of feed (on an as fed basis) each morning around 1000 h. This feed contained 18% crude protein and 88% dry matter. Cows were fed small amounts of feed to get them used to being handled on a daily basis, and not necessarily for weight gain or nutritional purposes. As a result, it was assumed that no feed was fed at Farm A during the study for model-development purposes, since 1.36 kg did not significantly add to cows' DMI. Feeding location did affect cattle movement across the stream, since cows were fed at one end of the pasture (Figure 3-7), 803 m away from the stream. No hay was fed during the study.

Farm B

Farm B is a dairy heifer operation located in Montgomery County, Virginia. The study period for this farm lasted for four months, from 10/31/01-2/28/02. Cattle numbers changed slightly during this time due to management practices. From 10/31/01-11/6/01, the animals consisted of seven mature Holstein cows, two of which were being milked. From 11/16/01-1/2/02, the field held six Holsteins, one Jersey, three Angus, and three Holstein calves. Starting on 1/2/02 through the end of the study period, the field contained five Holsteins and one Jersey, two of which were being milked. Holsteins averaged 680 kg each, Jerseys 499 kg, Angus around 454 kg, and the three calves weighed approximately 227 kg each. Data collected from the period when the three beef cows were in the study site were included with dairy data for this farm since it was difficult to distinguish between individual animals from videotapes.

An aerial photograph of the site at Farm B with outlined pasture boundaries is shown in Figure 3-10. A stream flows through the 5.99-ha pasture, providing the only source of water for cows. The stream is located at one end of the pasture, but there are areas to graze on both sides of the stream. This layout introduces the potential for cattle to cross the stream for grazing purposes.

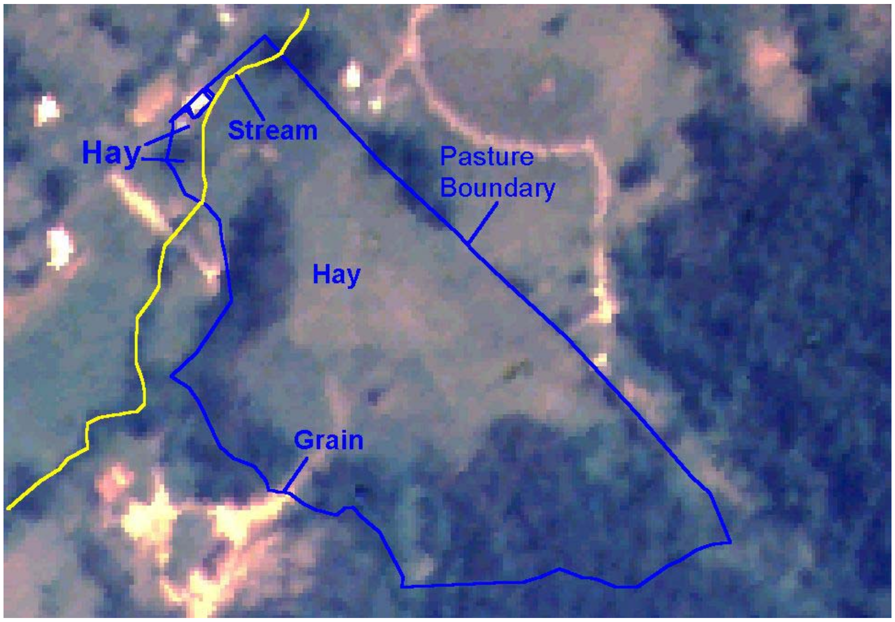

Figure 3-10: Map of Farm B.

The length of the stream at Farm B is 121 m. It is approximately 4.57 m wide, with an average depth of 0.21 m and an average flowrate of 0.118 m/s. The stream is well defined, and medium-sized rocks and stones cover the majority of the stream bottom. Stream banks are low enough throughout most of the stream to give cattle almost complete stream access. Approximately 7.5 m of the stream has banks on both sides that are 1.1 m high, which is too high for cattle to gain stream access. The stream section flowing through the pasture at Farm B is shown in Figure 3-11.

Figure 3-11: Stream section at Farm B.

A large portion of the pasture at Farm B is shaded, 2.14 ha, approximately one-third of the total pasture area. Forestland constitutes much of this shaded area and the rest is composed of random shade trees located throughout the pasture. A shade tree is located on the bank at one end of the stream, shading almost 9 m of the stream.

Mature cows were fed 9.07 kg/day of grain (as fed on a per cow basis) around 1000 h, at a location 279 m from the stream (Figure 3-10). Hay was fed during the winter months at several different locations throughout the pasture at approximately 102 m, 129 m, and 20 m from the stream.

Farm C

Farm C is a dairy located in Washington County, Virginia. The study period for this farm was from 11/17/01-2/28/02. Twenty-six yearling Holstein heifers comprised the study group, and had an estimated body weight gain of 0.9 kg/day during the study period.

A map of Farm C is presented in Figure 3-12. A stream flows through the 6.8-ha pasture, and provides the only source of water for cows in the pasture. Cows are fenced from the stream at Farm C except for a 16.2-m section where the stream is left open to cows. Grain and hay were fed on opposite sides of the stream, and in addition, there is grazing land on both sides of the stream. This arrangement makes it necessary for cattle to cross the stream to eat hay and to graze the majority of the pasture.

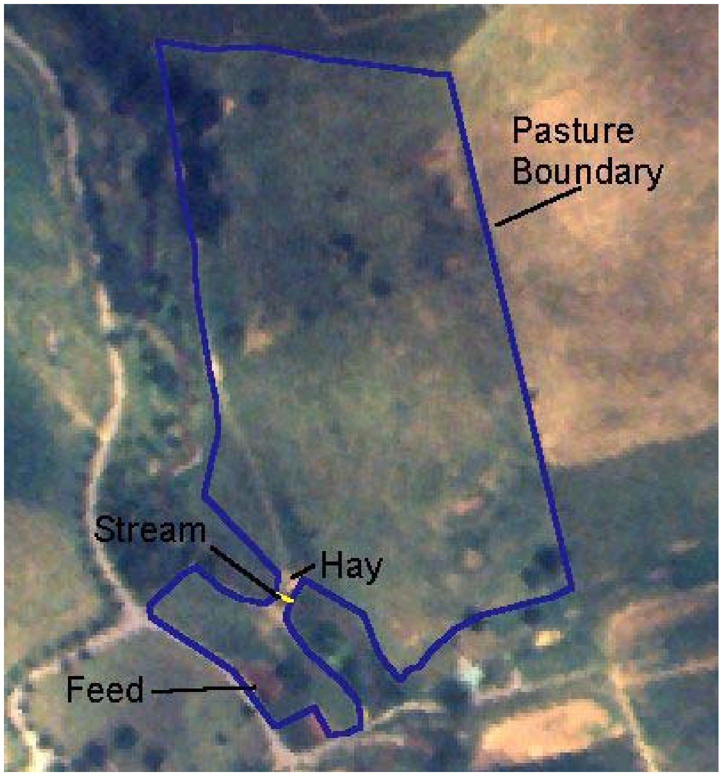

Figure 3-12: Map of Farm C.

The stream is 15.8 m wide at the 16.2-m crossing, with an average depth of 0.2 m and an average flowrate of 0.052 m/s. Medium-sized rocks are scattered on the stream bottom. The stream crossing at Farm C is shown in Figure 3-13.

Figure 3-13: Stream section at Farm C.

Trees provide the only shade in the pasture at Farm C, however only 4.6% of the pasture is shaded. The closest shade to the stream is a shade tree located 38 m away from the stream. This tree shades approximately 0.024-ha. There is no shade found along the 16.2-m section of the stream that cattle access.

During the study period, animals were fed 11.3 kg/day (as fed on a per cow basis) of a total mixed ration (TMR) around 1030 h. The TMR was fed 52.4 m away from the stream, while hay was fed on the other side of the stream 8 m away from the stream (Figure 3-12).

Farm D

Farm D is a beef operation located in Montgomery County, Virginia. The study period for this farm was from 11/20/01-1/30/02. Cattle numbers changed slightly during this time period due to management practices. From 11/20/01-1/6/02 the field held 26 cow/calf pairs, 16 grown cows were there from 1/6/02-1/12/02, eight grown cows from 1/12/02-1/23/02, and three grown cows from 1/23/02-1/30/02. The study herd consisted of a mixture of purebred Angus, Charolais, Hereford, Gelbvieh, and Simmental cattle.

A map of Farm D is shown in Figure 3-14. A small stream flows through the 6.07-ha pasture, providing cattle with their only source of water. The stream flows the entire length of the pasture, and there is grazing land on both sides, giving cattle a reason to cross the stream. Both grain and hay were fed to cattle on the same side of the stream during the study.

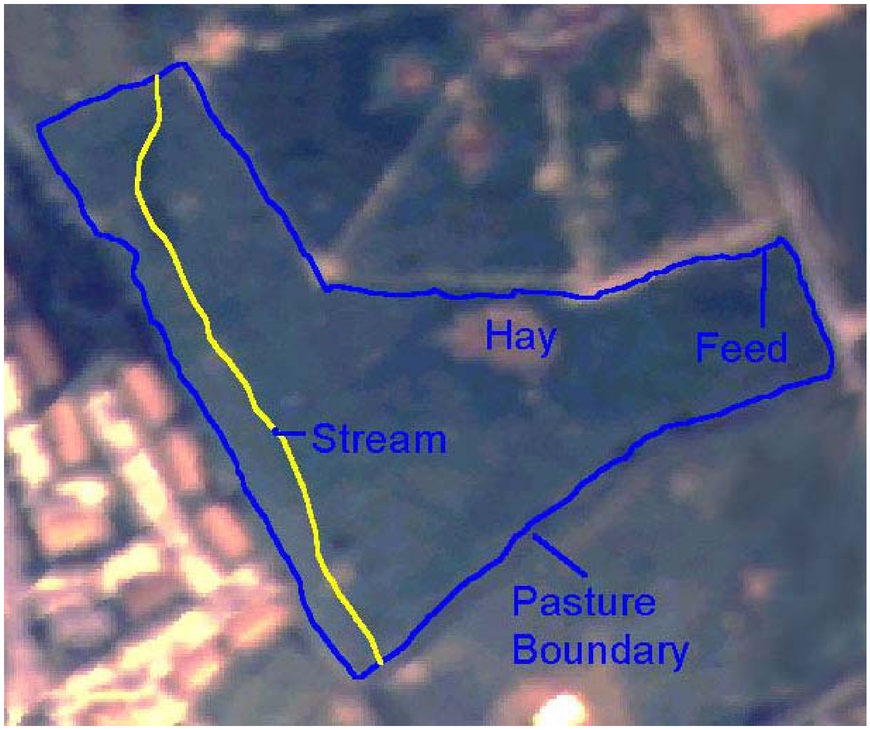

Figure 3-14: Map of Farm D.

The stream at Farm D is approximately 384 m in length. It is not very well defined for most of the stream length. It has an average width of 0.69 m, an average depth of 0.12 m, and an average flowrate of 0.031 m/s. Stream banks are not very steep (0.61 m), so cattle can access the entire stream. There is a substantial amount of marshy/muddy area on both sides of the stream. The stream bottom is covered with fine sediment and thick mud. Stream sections shown in Figure 3-15 and Figure 3-16 are representative of the stream at Farm D.

Figure 3-15: Stream section at Farm D.

Figure 3-16: Stream section at Farm D.

The pasture at Farm D has one tree as its primary source of shade. This tree is located 16 m from the stream, and shades an area of approximately 0.002 ha. The sun setting during late afternoon hours (around 1530-1630 h) also shades the stream as a result of trees located outside of the study pasture.

During the study, cattle were each fed 8.7 kg/day (as fed basis) of a corn silage/chicken litter mix, and given free choice hay. This ration was purely a maintenance diet, and not for weight-gaining purposes. The ration was fed 304 m away from the stream, while hay was fed 135 m away from the stream (Figure 3-14).

Farm E

Farm E is a beef farm located in Montgomery County, Virginia. The study period for this farm lasted from 11/26/01-1/30/02. The study group was composed of 26 cow/calf pairs. The oldest calf at the start of the study was around 1½ months of age. Calves estimated 0.5-1.4 kg of body weight gain per day during the study period. Fescue at Farm E was stockpiled for two months prior to cattle being brought to the study site. The practice of stockpiling fescue involves the postponement of grazing in a particular pasture so that forage will be available for cattle consumption during colder or dryer seasons when it would not ordinarily grow (Ball et al., 1996).

The stream flowing through Farm E provides the only water source for cattle. The pasture at Farm E is subdivided into two different sections, with cattle rotationally grazed through the two sections (Figure 3-17). As a result, it was necessary to move the surveillance equipment from the first section to the second section when cattle were moved. During the first half of the study period (11/26/01-1/9/02), only a portion of the stream was videotaped because the stream flowing through the pasture was too long to allow for the entire stream to be videotaped. Surveillance equipment was installed to record high traffic areas where the farmer had observed cattle loafing the majority of the time.

Direct field observations were conducted at this site in order to quantify the amount of time cattle spent in the videotaped portion of the stream and evaluate the accuracy of data collected from surveillance systems. Direct field observations were conducted on 12/1/01 and 12/17/01. Observations began at 0700 h and lasted until 1800 h. Cattle activity was observed from a pickup truck parked in the field in a location that allowed for uninterrupted observation of stream activity. Observation was continuous throughout the day; all cattle stream activity was observed. The amounts of time cattle spent in the stream and the point from which they accessed the stream were recorded. These results were later compared to results interpreted from video surveillance of the stream segment.

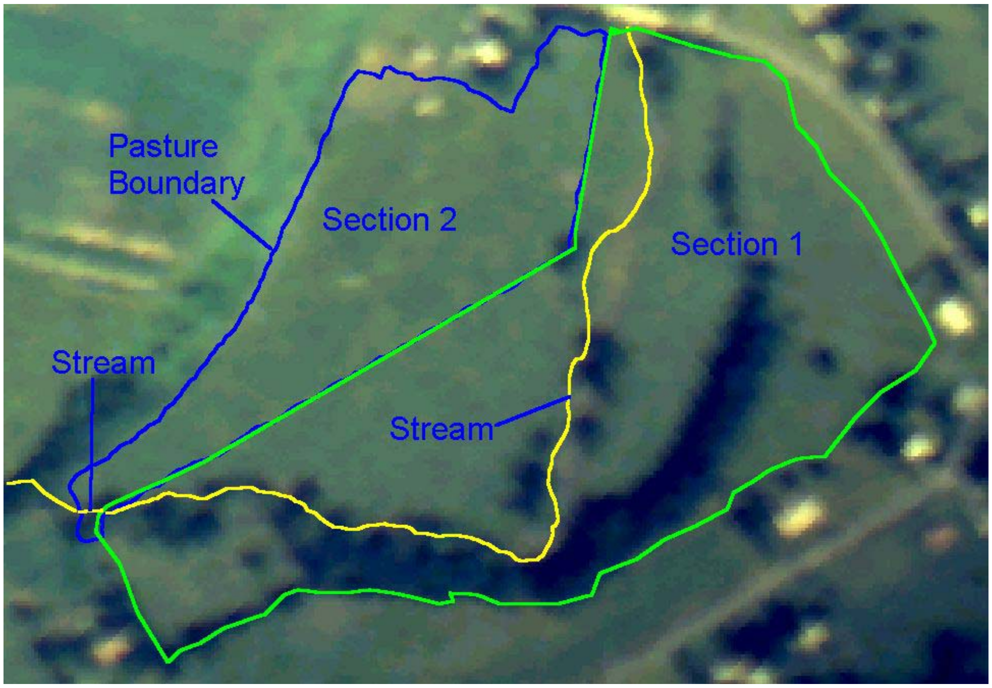

Figure 3-17: Map of Farm E.

The stream flows for 670 m through the first section of the study site, which is 9.7 ha in size. The stream is well defined, and stream banks are fairly steep in some areas (1.22-1.52m), making it impossible for cattle to have access to the entire stream. Cattle have approximately four specific areas at which they cross the stream where stream banks are not as steep. There is pasture to be grazed on both sides of the stream, giving cattle a reason to cross the stream.

The stream has an average width of 9.14 m and meanders through the pasture for 670 m. The stream has an average depth of 0.34 m and an average flowrate of 0.148 m/s. A number of small to medium size stones cover the bottom of the stream in the first study section. Representative pictures of the stream flowing through the first study section at Farm E are shown in Figure 3-18 and Figure 3-19.

Figure 3-18: Stream section at Farm E during the first half of the study.

Figure 3-19: Stream section at Farm E during the first half of the study.

A fair amount of shade (2.11 ha) is found in the first study section, accounting for 21.8% of the pasture area. Approximately 34% of this shaded area is located around the stream, shading about 337 m of the stream.

The second half of the study lasted from 1/9/02 through 1/30/02. The stream section running through the 3.8-ha pasture observed during this part of the study was videotaped in its entirety. The stream is 16 m long and 11.3 m wide in this section, having an average depth of 0.3 m and flowrate of 0.148 m/s. The bottom of the stream consists of fairly large rock outcroppings and larger stones. Banks are not steep, allowing cattle to access the entire stream. The section of stream at the second study section is shown in Figure 3-20.

Figure 3-20: Stream section at Farm E during the second half of the study.

Trees shade the entire stream section at the second study section, and there is also a small area of trees providing shade on the opposite end of the pasture. This shade accounts for only 2.6% of the pasture area.

Pasture remained the only source of feed for cattle throughout the study period in both sides of the pasture; no feed ration or hay was fed. The stream was the only source of water in both sides of the pasture.

Field Research Procedures

Cattle stream behavior was videotaped on each farm using video surveillance cameras and time-lapse VCRs. Tapes from each farm were then viewed to determine the amount of time cattle spent standing in streams. Tapes were viewed frame by frame for accuracy. A tape was advanced frame by frame until a cow was seen entering the stream. The date and time of day were recorded to the nearest 15 seconds, and the videotape was advanced frame by frame until the animal was seen exiting the stream. The time the cow exited the stream was then recorded, and the total amount of time the animal stood in the stream was calculated.

Times were interpolated when cameras switched views and the actual time cows entered or exited the stream were not available. An example of this would be when a cow was seen nearing the stream in one camera view just before the view changed, and when the tape cycled back to the same camera view, the cow was seen standing in the stream. In this instance, the time interval among camera views was taken into account together with the distance the animal was from the stream and the speed at which it was traveling towards the stream. If the animal was within several feet of the stream and still moving (not stopping to graze) just before the camera view changed, 5-15 seconds after the time the view changed was recorded as the time the cow entered the stream. This again depended on the distance from the stream and how fast the animal was moving. If it did not appear the animal would reach the stream in 15 seconds, then 20-25 seconds were added to the time the view changed. Interpolation between camera views was conducted using best judgment. Several days of video from each farm were viewed before beginning interpretation for familiarization of movement and behavior patterns on each farm.

For each cow standing in the stream, the time of day and length of time the animal stood in the stream was recorded. Zero values were recorded for days when no cows were in streams on any day. The total daily amount of time cattle stood in streams for each farm was calculated by summing the product of the number of cows and the amount of time they stood in the streams, as found in Equation 3-1:

$$TT = \sum_{day} t \times n \qquad [3\text{-}1]$$

Where: TT = total daily amount of time cows spent in the stream (cows*min).

n = number of cows in the stream at a given time of day.

t = length of time cows spent in the stream at a given time of day (min).

For each farm, the average daily time spent in streams per cow per day was calculated using Equation 3-2:

$$ADT = \frac{TT}{N} \qquad [3\text{-}2]$$

Where: ADT = average daily time spent in stream (min $day^{-1}cow^{-1}$).

N = total number of cows in the pasture for that day.

Individual cattle could not be differentiated from the herd on the videotapes. This inability did not present a problem, however, since times per cow were calculated on an average basis.

Statistical Analysis

A database was compiled with weather data, feed attributes for forage, ration, and hay, pasture characteristics, and average total daily time spent in streams for each farm (Table A-1).

Beef vs. Dairy Analysis

The first step in the statistical analysis procedure was to determine if there was a significant difference between average daily time spent in streams by beef cattle and dairy heifers studied. Average daily times spent in streams for the two beef farms were compared with average daily times spent in streams for the three dairy farms. Sample sizes and sample variances were both unequal; therefore, a Welch's test was used to determine if there was a significant difference between population means at $\alpha=0.05$.

Regression Analysis

The three purposes of multiple linear regressions are to estimate coefficients in the complete model, determine which variables have a significant effect on the response, and to determine the best equation for predicting new responses (Walpole and Myers, 1993). Standard sequential procedures for selecting the best possible regression equation are used when many variables are under investigation; individual t-tests are not used since they do not evaluate the interdependency among variables.

The more common sequential procedures are stepwise regression, forward selection, and backward elimination. Each procedure involves either adding or removing variables sequentially from the equation until a final regression equation is achieved. These procedures are all designed to include a combination of all significant variables in the final model, but there is no guarantee that this will always happen. While stepwise, forward, and backward selections are efficient methods, they do not always provide the best possible subsets of variables (Hocking, 1976; Walpole and Myers, 1993).

Walpole and Myers (1993) recommend using an all possible subset regression to determine all combinations of variables, provided computer speed is adequate for the procedure. It is recommended that the sequential methods previously discussed be used only if computer speed disallows the use of an all possible regression routine. Neter et al. (1996) points out that stepwise, forward, and backward selections only identify one regression model as the best even though it may not be; whereas an all possible subset regression identifies several good models that can be further investigated.

A multiple linear regression analysis was conducted on collected data to select a relationship between the amount of time cows spend in streams as a function of significant factors affecting their behavior. A suitable model would fit well when it explained a large portion of the variability of the response using significant model parameters. New responses are predicted when model parameters are inputted into the generated equation to get a new response, not a previously measured response on which the model was built. In this case, measured parameters such as average daily temperature and feed parameters are inputted into the generated equation to predict how much time cows spend in streams (min $day^{-1}cow^{-1}$).

A multiple regression procedure "*All Possible Regressions*" in SAS (Statistical Analysis Software release 8.2, 2001) was used to generate and to select the best possible models from all parameter combinations. Data from Farms A, B, C, and E were used in the regression procedure (250 days of data) and data from Farm D was saved for model evaluation procedures (47 days of data). The average daily time cows spent in streams (min $day^{-1}cow^{-1}$) was used as the dependent variable, and the 33 possible regressors used in the analysis are found in Table 3-7.

Table 3-7: Variables used in the regression analysis.

Parameter Name	Model Abbreviation	Units
Maximum daily temperature	maxtemp	^oC
Minimum daily temperature	mintemp	^oC
Mean daily temperature	avgtemp	^oC
Daily precipitation	precip	cm
Average daily wind speed	wind	km/h
Average daily relative humidity	rh	%
Dry matter content of pasture	fdm	% as fed
Crude protein content of pasture	fcp	% dry basis
Neutral detergent fiber content of pasture	fndf	% dry basis
Acid detergent fiber content of pasture	fadf	% dry basis
Total digestible nutrient content of pasture	ftdn	% dry basis

Table 3-7 (continued): Variables used in the regression analysis.

Parameter Name	Model Abbreviation	Units
Dry matter content of hay	hdm	% as fed
Crude protein content of hay	hcp	% dry basis
Neutral detergent fiber content of hay	fndf	% dry basis
Acid detergent fiber content of hay	fadf	% dry basis
Total digestible nutrient content of hay	ftdn	% dry basis
Dry matter content of feed	gdm	% as fed
Crude protein content of feed	gcp	% dry basis
Neutral detergent fiber content of feed	gndf	% dry basis
Acid detergent fiber content of feed	gadf	% dry basis
Total digestible nutrient content of feed	gtdn	% dry basis
Total shaded pasture area	ts	ha
Percent of total shaded area located around the stream	pass	%
Percent length of the stream that is shaded	plss	%
Pasture stocking density	sden	animals/ha
Pasture area	pa	ha
Distance from hay feeding location to stream	dhw	m
Distance from grain feeding location to stream	dgw	m
Pasture length/width ratio	ltw	m/m
Stream length	sl	m
Ratio of total shaded area to pasture size	tspa	ha/ha
Distance from stream to closest shade	dcs	m
Hay feeding indicator*	hay	0 or 1

*An explanation of this parameter is given in the results and discussion section on effects of feed.

SAS yielded the best fitting models from the *All PossibleRregressions* routine in sections; the first section used one parameter to fit cattle presence in streams, the second used two parameters, and so on (Appendix B). Subset model regressions within each section were ordered based on the highest R^2 and lowest C(p) values. Mallow's C(p) statistic provides an estimate of the total mean squared error (MSE) of the fitted values for each subset regression, with better fitting models having lower C(p) values. The use of the C(p) statistic aids in the prevention of model over-fitting. The coefficient of determination, R^2, gives a measure of the amount of variation of the response when predictor variables are used. R^2 values vary between 0 and 1, with better fitting models having higher values.

Model subsets at the top of each regression output section from SAS had the highest R^2 and lowest C(p) value, representing the best fitting model using that number of parameters. The first model from each of the 14 output sections was chosen as a candidate to be further investigated for fit. Further investigation consisted of accounting for daily correlation of repeated measures by farm, and generating residual plots for analysis.

A multiple linear regression procedure was run for each of the final 14 models while using an exponential decay model to account for daily correlation among measurements. Akaike's Information Criterion (AIC) and an estimated R^2 value were used as the basis for determining which model best fit collected data. Smaller AIC values indicate better-fitting models, as do larger R^2 values. An estimated R^2 value was calculated because the R^2 assumption is based on independence, and the model in this case is longitudinal with daily correlation among measurements. The following relationships were used to calculate estimated R^2 values for each model to aid in the selection of the best-fit model:

$$Resid2 = [MDC - pred(MDC)]^2 \qquad [3\text{-}3]$$

Where: $Resid2$ = residual (min day^{-1}cow^{-1})^2

MDC = measured time in streams (min day^{-1}cow^{-1})

$pred(MDC)$ = predicted min day^{-1}cow^{-1}

$$MSEfull = \frac{\sum Resid2}{obs} \qquad [3\text{-}4]$$

Where: $MSEfull$ = variation among predicted time in streams

obs = number of observations

$$R^2 = 1 - \frac{MSEfull}{MSTO} \qquad [3\text{-}5]$$

Where: $MSTO$ = variation among measured time in streams

The selection of a prediction model involves many considerations. The best prediction model was selected based on the lowest AIC value and the highest R^2 value, while utilizing a reasonable number of parameters.

Model Evaluation

The selected prediction model was evaluated using two separate methods in order to determine the model's performance predicting new responses. Data from Farm D were withheld from the model selection routine to be used for model evaluation. Observations for Farm D resulted in the collection of 47 days of data, starting the last week of November and lasting through the end of January.

Significant parameters for Farm D identified in the final prediction model were used to calculate predicted daily time in streams for Farm D. These predicted times were then compared to the measured amount of time cows stood in the stream at Farm D, which were recorded during surveillance observation.

Another evaluation was conducted to assess the performance of the prediction equation. Fifty days of data were randomly selected from the 250 days of data collected on Farms A, B, C, and E, that were used in the regression analysis procedure to build the prediction model. Predicted time in streams was calculated for each of these 50 days using the prediction equation. Calculated predicted daily time cows spent in streams for these 50 days were then compared to measured time in streams (from surveillance observation) to determine the effectiveness of the prediction equation.

Chapter 4 : Results and Discussion

The overall goal of this study was to gain an estimate of the amount of time cattle spend in streams, due to its significant impact on the amount of fecal coliform directly deposited in streams. Study results are presented and discussed in this section, followed by a comparison of beef and dairy results, and results from individual farms. Results from individual farms are compared and significant parameters influencing cattle presence in streams are discussed. A mathematical model for predicting cattle presence in streams is then presented followed by a discussion of the importance of results to the development of TMDL plans.

Sporadic, unpredictable equipment failure occurred throughout the study period on all farms, causing occasional missing data. VCR malfunctions and overall system power loss contributed to some of these failures. Cattle behavior accounted for the remainder of these failures; mostly due to cattle chewing on power cords and camera wires.

Equipment necessary for recording at night was beyond the project budget; therefore streams were only videotaped during daylight hours. Study results presented in this section represent average time spent in streams during daylight hours. For study purposes, this time is assumed to be the total amount of time spent in streams for the entire day; it is assumed that no cows are present in streams throughout the night.

Direct nighttime observations were not conducted to assess the validity of this assumption; however, video-footage near dark and at sunrise on several farms revealed cattle movement patterns, and suggested this to be a reasonable assumption. On videotape, cattle were seen migrating away from stream areas to far sides of pastures during evening hours, and returning to stream areas after sunrise the following morning. Cattle were observed to spend their time at night in grazing areas away from water in a study on watering behavior of cattle in arid Australia reviewed by Squires (1981). Cattle migrated to water just before or after sunrise, remained around watering areas for much of the day before leaving for grazing areas late in the afternoon.

During warmer summer months (temperatures above 25^{o}C), it is reasonable to assume that cattle may spend the majority of their day resting to conserve energy and stay cooler since their threshold for sweating is 25^{o}C. At these temperatures, cattle would then be more active during the evening hours and throughout the night. Their need for water during the night might then increase due to increased activity. This cattle behavior study took place mostly during cooler parts of the year when temperatures were generally much below 25°C, which meant that cattle were most likely not more active at night, and their water needs during the night most likely did not increase as a result.

Overall Results

A total of 230 animal-months of data were collected during the study. Data collected is the equivalent of one cow being observed for 230 months. The total average time cows spent in streams for all farms investigated in this study was 10.12 min $day^{-1}cow^{-1}$. The greatest amount of time spent in streams occurred at Farm C, while the least amount occurred at Farm E (Table 4-1). November had the highest overall daily average time in streams of all of the months studied. August and September, surprisingly, had the smallest overall average daily time, but these averages were calculated based on data collected from only one farm (Farm A). Excluding August and September when only one farm was being studied, cattle spent the smallest average amount of time in streams during the month of December. This result parallels results from Holter and Urban (1992), who combined water intake research from four different studies and concluded water intake of dairy cows was the lowest in late December (it was not reported whether this result was observed for lactating or nonlacting cows, or both).

Table 4-1: Average daily time in streams (min $day^{-1}cow^{-1}$) for each month.

	August	September	October	November	December	January	February	Overall
Farm A	3.75 (10)*	3.82 (21)*	9.24 (20)*	7.97 (10)*	►	►	►	6.27 (61)*
Farm B	►	►	13 (1)*	11.39 (30)*	5.74 (25)*	9.51 (31)*	8.69 (28)*	9.01 (115)*
Farm C	►	►	►	24.13 (14)*	18.34 (8)*	14.93 (21)*	10.74 (28)*	15.48 (71)*
Farm D	►	►	►	18.42 (9)*	7.5 (19)*	13.8 (19)*	►	12.14 (47)*
Farm E	►	►	►	6.12 (3)*	4.59 (11)*	3.08 (10)*	►	4.15 (24)*
Overall	3.75 (10)*	3.82 (21)*	9.42 (21)*	14.3 (66)*	7.7 (63)*	11.5 (81)*	9.7 (56)*	

► No averages are available because no data were collected during this month at this site.
* The number of days of data used to calculate averages for each month.

Beef vs. Dairy Results

Data were analyzed to determine if a significant difference exists between average time spent in streams by beef cattle and dairy heifers studied. Using a Welch's Test, no significant difference (p=0.82) was found between population means (Table 4-2). The physiological condition of beef and dairy cattle studied were approximately equal, since non-milking dairy heifers were observed. This physical similarity may explain the lack of difference between the amount of time beef and dairy cows spent in streams, since cows producing milk have an increased need to consume water (Winchester and Morris, 1956; Squires, 1981).

Table 4-2: Summary statistics for beef farms and dairy farms.

	Average Time (min $day^{-1}cow^{-1}$)	SD (min)	Range (min $day^{-1}cow^{-1}$)	Number of Days Observed
Overall	10.12	7.25	1.51- 40.37	318
Beef	9.44	8.6	1.51 – 34.13	71
Dairy	10.19	6.71	0.0 – 40.37	247

The variation of average daily time for beef farms was slightly higher than the variation of average daily time for dairy farms. This result could be due in part to a much smaller sample size for beef farms, the result of rotational grazing and equipment malfunctions; 247 days of dairy observation compared to 71 days of beef observation.

Figure 4-1 compares the monthly average daily time spent in streams by beef cattle and dairy heifers. This figure reinforces the similarity of time spent in streams by type of cow. Cows spent less time in streams during the month of November, which corresponds to the lowest monthly precipitation average; 0.037 cm for Blacksburg and 0.004 cm for Washington county.

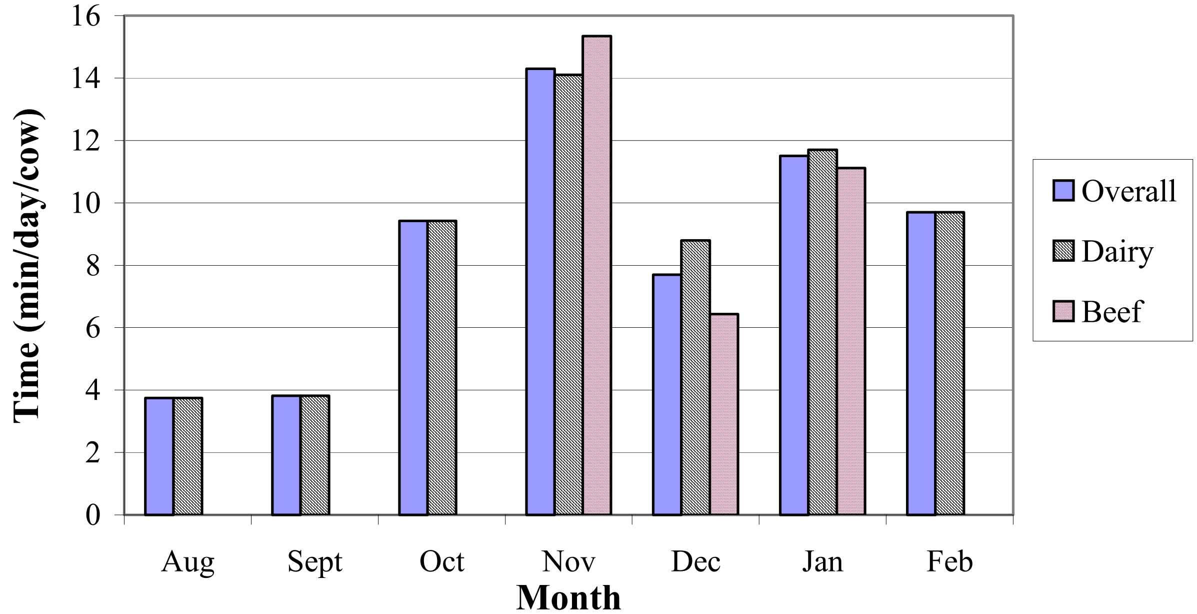

Figure 4-1: Average daily time spent in streams each month by cow type.

Figure 4-2 compares average daily time spent in the stream at each farm. Farm A, Farm B, and Farm C are dairy heifers operations, while Farm D and Farm E are beef operations. Farm C is located in Washington County, VA, while all other farms are located in Montgomery County, VA. Figures 4-1 and 4-2 are presented to give an idea of overall study results, and will be discussed in more detail in subsequent sections.

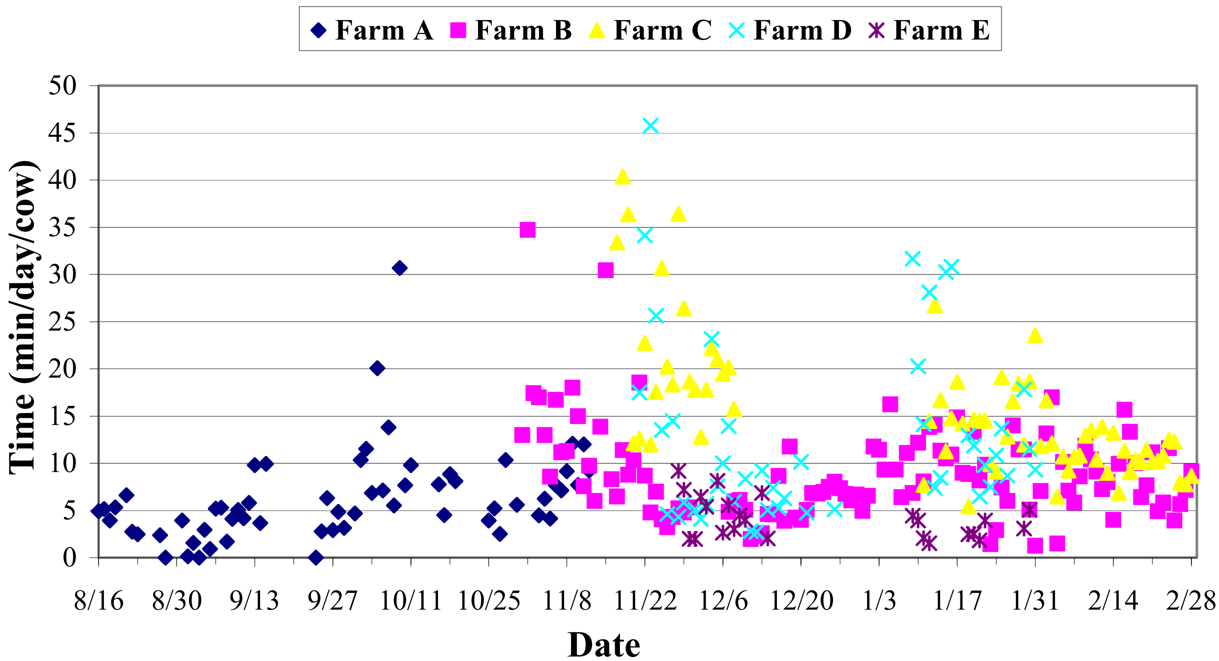

Figure 4-2: Average daily time spent in streams at each farm.

Farm D had the greatest daily amount of time spent in streams (45.8 min/cow), occurring on 11/23/01. The smallest daily amount of time spent in streams occurred at Farm A, and was 0 min/cow, which was recorded on three different occasions, 8/28/01, 9/3/01, and 9/24/01. This lack of cows in the stream at Farm A may be explained by the amount of rain that fell before, and on those days, puddling at different locations around the pasture. This puddle effect may have provided alternate water sources for cows at Farm A during that time. There is also a possibility that on these days, cows visited the stream during the night when the stream was not being videotaped.

Individual Farm Results

Results from individual farms are presented in this section to enable the comparison of average daily time spent in streams between farms.

Farm A

The study period for dairy heifers at Farm A lasted for 88 days, from 8/15/01 through 11/12/01. Only 61 full days were observed during this study period, due to equipment failure resulting from power loss and cow behavior. Only 10 days were observed in August and

November due to rotational grazing. Cows spent an average of 6.27 min $day^{-1}cow^{-1}$ during the observed 61 days, and the SD during this time was 4.88 minutes (Table 4-3).

Table 4-3: Summary data for Farm A.

Study Period	Average Time (min $day^{-1}cow^{-1}$)	SD (min)	Range (min $day^{1}cow^{-1}$)	Average Daily Temp (^{o}C)	Average Daily Precip (cm)	Number of Days Observed
Overall	6.27	4.88	0.0 – 30.67	15.25	0.141	61
Aug	3.75	1.81	0.0 – 6.63	21.28	0.184	10
Sept	3.82	2.71	0.0 – 9.94	16.43	0.147	21
Oct	9.24	6.25	2.52 – 30.67	11.02	0.106	20
Nov	7.97	2.59	4.13 – 12.08	8.83	0.037	10

The stream at Farm A is located in one corner of the pasture (Figure 4-3), requiring cows to travel explicitly to the stream for the purpose of drinking. Cows did not need to cross the stream to get to other sections of the pasture as they did at other farms. Cows were fed in the morning around 1000 h and loafed around the feeding area in the shade after feeding. The stream at Farm A is located 500 m from the feeding spot. Direct observation in conjunction with videotape footage revealed cows generally traveled this distance once a day, usually sometime between 1100 h and 1400 h. After loafing around the stream and drinking, cows were observed to migrate back up the pasture, continuing to graze.

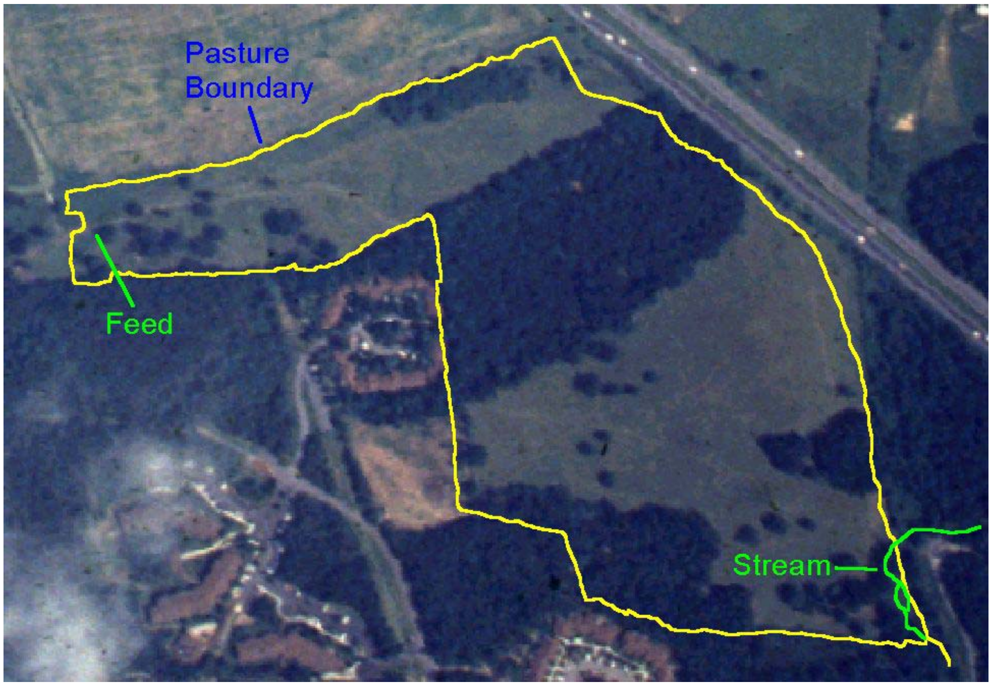

Figure 4-3: Map of Farm A.

Two observation days (10/9/01 and 10/5/01) during the study period at Farm A had much higher average daily time in the stream than other days during the study period (Figure 4-4). These values were 30.67 min/cow and 20.06 min/cow, respectively. No unusual weather patterns occurred during these days. High temperatures were 17.2 and 24.4^{o} C, respectively, not noticeably different from weather on previous or subsequent days, although there was not a considerable amount of cloud cover on 10/9.

No cows were observed in the stream on 8/28/01, 9/3/01, and 9/24/01, which is most likely the result of rainy weather and water puddling in different locations around the field. High temperatures were 27.2, 19.4, and 17.8^{o} C, respectively, with a trace of precipitation occurring on 9/3, and 1.7 cm of rain occurring on 9/24. Mostly cloudy skies were reported on 9/3 and 9/24. The remainder of daily times spent in the stream for Farm A had a range between 2 and 12 min day^{-1}cow^{-1}, with the average being 6.27 min day^{-1}cow^{-1}.

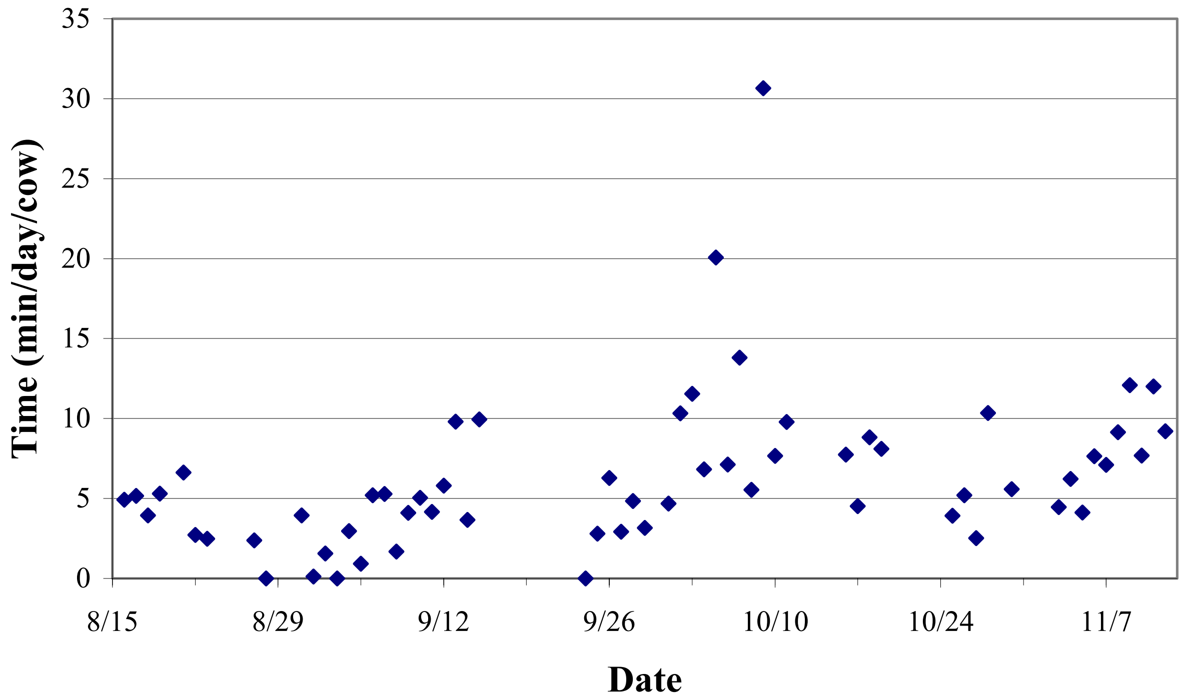

Figure 4-4: Average daily time spent in the stream at Farm A.

Farm A had a lower than expected overall average daily time in streams of 6.27 min day^{-1} cow^{-1}. A higher value was expected since the majority of the observation period at Farm A occurred during warmer months when it seems cows would drink more and try to cool down more by standing in streams. The average amount of time in the stream for October and November was surprisingly greater than that for August and September. This result could be due to lower pasture quality and a lack of rain towards the end of the study period; no rain was recorded for days studied during November. By the end of the study period, the water level of the stream was very low. In addition, cows at this location did not need to cross the stream for feeding/grazing purposes as they did on other farms; they just visited the stream to drink and cool down.

Farm B

The study period for dairy cows at Farm B was 121 days, from 10/31/01 through 2/28/02, during which 115 days of data were collected. Six days of data were lost due to camera problems. The average time a cow spent in the stream during the study period was 9.01 min/day, and the SD of the average was 5.06 minutes (Table 4-4).

Table 4-4: Summary data for Farm B.

Study Period	Average Time (min $day^{-1}cow^{-1}$)	SD (min)	Range (min $day^{-1}cow^{-1}$)	Average Daily Temp (°C)	Average Daily Precip (cm)	Number of Days Observed
Overall	9.01	5.06	1.25 – 34.71	4.65	0.132	115
Oct	13	0	13.0	11.02	0.106	1
Nov	11.39	7.25	3.23 – 34.71	8.83	0.037	30
Dec	5.74	2.11	1.96 – 8.65	4.39	0.210	25
Jan	9.51	3.7	1.25 – 16.25	2.62	0.226	31
Feb	8.69	3.51	1.5 – 17.0	2.54	0.070	28

The stream at Farm B is located at one end of the pasture (Figure 4-5), but unlike at Farm A, there are areas to graze on both sides of the stream. Cattle not only drank from the stream, but also crossed the stream to get to the other side for grazing purposes. Cows were fed grain daily around 1000 h at a location approximately 900 m from the stream. Hay was free fed during winter months (late November-February) at several different locations throughout the pasture. Two of the locations for feeding hay were located on the opposite side of the stream from where grain was fed, causing cattle to cross the stream to get from one feeding location to another, which increased cattle presence in streams.

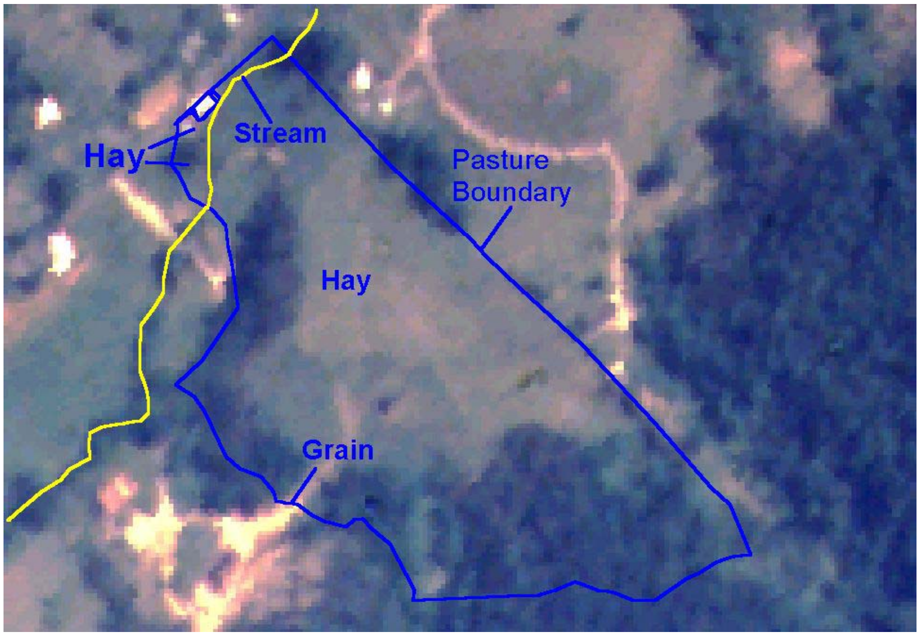

Figure 4-5: Map of Farm B.

The two largest average daily times spent in the stream by cows at Farm B were 34.67 min/cow and 30.43 min/cow, occurring on 11/1/01 and 11/15/01 (Figure 4-6). No noteworthy climatic events occurred on either day. The respective high temperatures were 21.1 and 18.9^{o} C, which were average for the time of year (Table 3-4). The three lowest daily times were recorded within 11 days of one another, occurring on 1/23/02, 1/31/02, and 2/4/02. These times were 1.42 min/cow, 1.25 min/cow, and 1.5 min/cow, respectively. A heavy rain of 1.93 cm occurred on 1/23, when the high temperature was 12.8^{o} C under mostly cloudy skies. On 2/4, 0.51 cm of snow fell, and the high temperature was only 0.6^{o} C. No significant weather occurred on 1/31, although it was the second day in a row of unusually warm weather with a high of 22.8^{o} C (Table 3-4). The remainder of the times Farm B ranged between 2 and 18 min day^{-1} cow^{-1}, with the average being 9.01 min day^{-1} cow^{-1}.

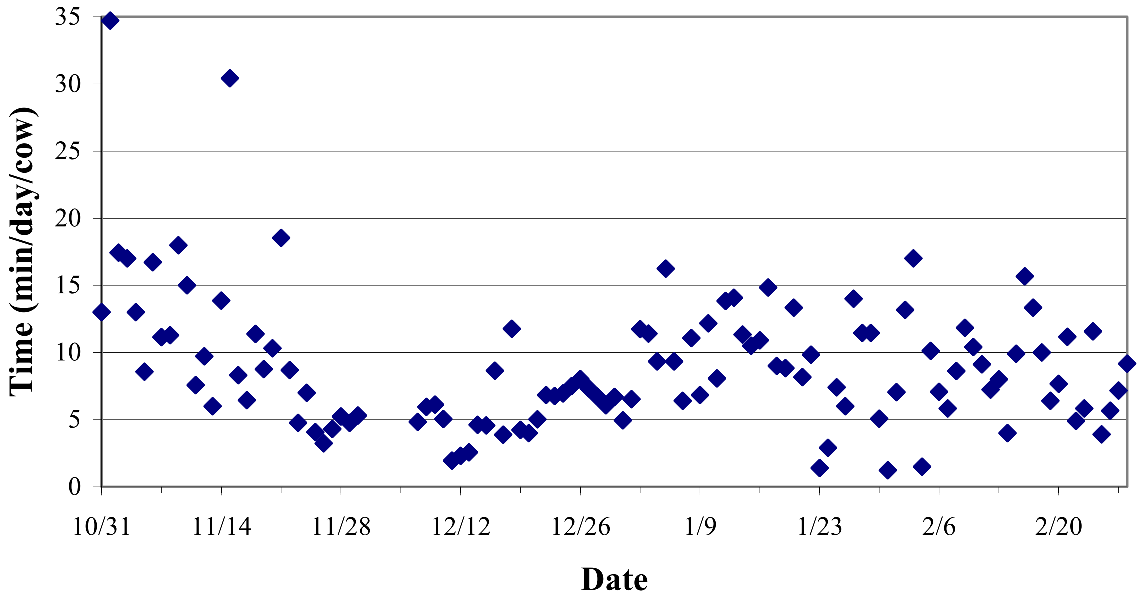

Figure 4-6: Average daily time spent in the stream at Farm B.

Cows at Farm B spent the least amount of time in the stream during the month of December, which is again similar to results from Holter and Urban (1992), concluding that water intake of dairy cows was the lowest in late December (researchers did not specify if this result was for lactating or nonlactating cows). Dry matter content of pasture tested at Farm B was the highest during the month of December, which does not explain the lower average time in streams that occurred in December. Lower daily temperatures, however, could comprise the decreased need for water, decreasing time in streams. The amount of total digestible nutrients in the pasture was also lower in December compared with other months during the study period, possibly contributing to a decreased need for water intake.

Farm C

The observation period for dairy heifers at Farm C lasted for a total of 103 days, from 11/17/01 through 2/28/02, during which the behavior of 26 heifers were observed. Equipment failure attributed to cows resulted in the collection of only 71 days of data during this time. The average time spent in streams for cows over the course of the study period at this site was 15.48 min day^{-1}cow^{-1}, with a SD of 7.22 minutes (Table 4-5). Only eight days were observed during the month of December due to equipment problems.

Table 4-5: Summary data for Farm C.

Study Period	Average Time (min $day^{-1} cow^{-1}$)	SD (min)	Range (min $day^{-1} cow^{-1}$)	Average Daily Temp (°C)	Average Daily Precip (cm)	Number of Days Observed
Overall	15.48	7.22	6.47 – 40.37	6.22	0.003	71
Nov	24.13	9.8	11.95 – 40.37	11.01	0.001	14
Dec	18.34	3.03	12.78 – 22.15	9.73	0.000	8
Jan	14.93	5.03	7.71 – 26.71	5.41	0.007	21
Feb	10.74	2.24	6.47 – 16.63	3.47	0.002	28

Cattle stream access at Farm C is limited to a 16.2-m section that is meant for drinking and crossing (Figure 4-7). Feed was fed on one side of the stream and hay was fed on the opposite side, making it necessary for cattle to cross the stream often. Feed was fed around 1030 h daily, while hay was constantly available during winter months (December-February). Cows also crossed the stream for grazing purposes. Cows were observed visiting the stream at different times throughout the day; no set pattern was observed with regard to time of day.

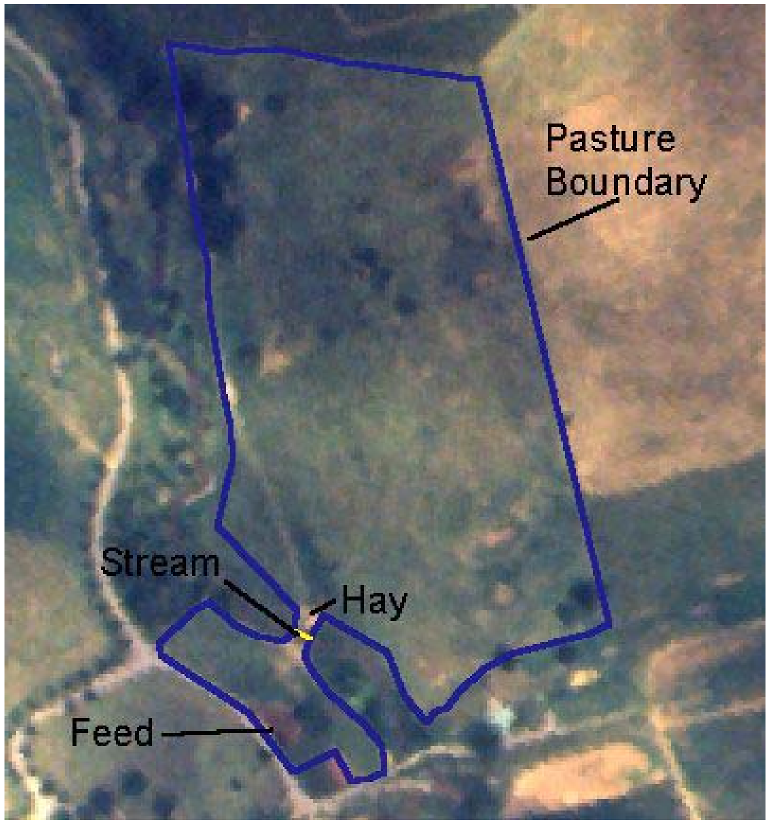

Figure 4-7: Map of Farm C.

The largest daily times in the stream at Farm C were greater than those at other farms. Four observation days during the study period at Farm C were much higher than other days during the study period. These days were 11/17/01, 11/18/01, 11/19/01, and 11/28/01, and the values recorded for these days were 33.38 min/cow, 40.37 min/cow, 36.38 min/cow, and 36.42 min/cow, respectively (Figure 4-8). No precipitation was recorded on these days, relative humidity and solar radiation were average, and daily high temperatures for these days were 21.1, 19.4, 17.2, and 23.3^{o} C, respectively. These temperatures were slightly higher than normal for that time of year, particularly the 23.3^{o} C high recorded on 11/28 (Table 3-4).

The lowest daily times at Farm C were also larger than the lowest daily times at other farms. The least amount of time spent in the stream was recorded on 2/4/02 and 2/15/02, when cattle spent 6.47 min/cow and 6.86 min/cow, respectively, in the stream. High temperatures for these two days were –0.6 and 11.7^{o}C, respectively, neither of which were extremes during this time. In addition, no rainfall was reported for these days, and relative humidity and solar radiation were average. A total of 36.6% of the average daily times at Farm C fell between ± 3 minutes of the average for the site, which was 15.48 min $day^{-1}cow^{-1}$.

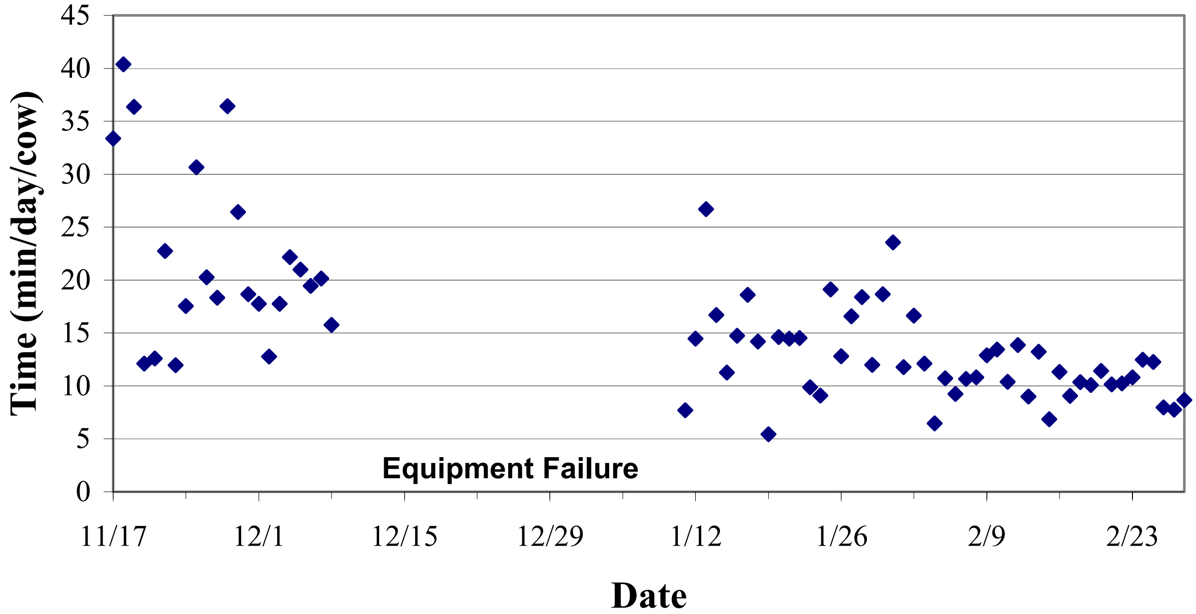

Figure 4-8: Average daily time spent in the stream at Farm C.

As previously discussed, the largest overall amount of time cows spent in streams from all sites studied occurred at Farm C. Farm C also had highest monthly averages for the amount of time cows spent in streams. One reason for these large times is the result of cows being forced to cross the stream more than at other farms. Both feed and hay were fed daily on opposite sides of the stream at Farm C, and there were also areas to graze on both sides of the stream. At other farms, feed and hay were generally fed on the same side of the stream, and there was not as much grazing land on the opposite side of the stream as there was at Farm C. Farm C was located an hour and a half southwest of the other study sites, but climatic conditions were approximately the same for both locations during the study period. There was at most a ± 3^{o} C difference in temperatures between Washington County and Montgomery County on any given day during the study. Washington County did, however, receive much less precipitation than Montgomery County during the study period; Washington County received less than 0.5 mm (Figure 3-4).

Farm D

The study period for beef cattle at Farm D lasted for 71 days, from 11/21/01 through 1/31/02, during which 47 days of data were collected. Twenty-six cow-calf pairs were present in the field through December, and afterwards the field contained mature beef cattle. Each cow spent an average of 12.14 min/day in the stream throughout the observation period (Table 4-6). The SD during this time was calculated to be 9.49 minutes.

Table 4-6: Summary data for Farm D.

Study Period	**Average Time (min day^{-1}cow^{-1})**	**SD (min)**	**Range (min day^{-1}cow^{-1})**	**Average Daily Temp (°C)**	**Average Daily Precip (cm)**	**Number of Days Observed**
Overall	12.14	9.49	2.72 – 34.13	4.44	0.206	47
Nov	18.42	14.3	4.29 – 34.13	8.83	0.037	9
Dec	7.5	4.7	2.72 – 23.15	4.39	0.210	19
Jan	13.8	8.49	4.35 – 31.66	2.62	0.226	19

The stream at Farm D runs the length of the pasture, and cattle graze on both sides of the stream, making it necessary for them to cross the stream (Figure 4-9). Feed was fed daily around 1030-1100 h at a location 304 m from the stream, while hay was continuously available at a distance 135 m from the stream. Hay and feed were both fed on the same side of the stream, so cattle did not have to cross the stream for eating purposes (other than grazing) as they may have at other study sites. Cattle were observed to visit the stream at different times throughout the day, no set pattern was observed with regard to time of day.

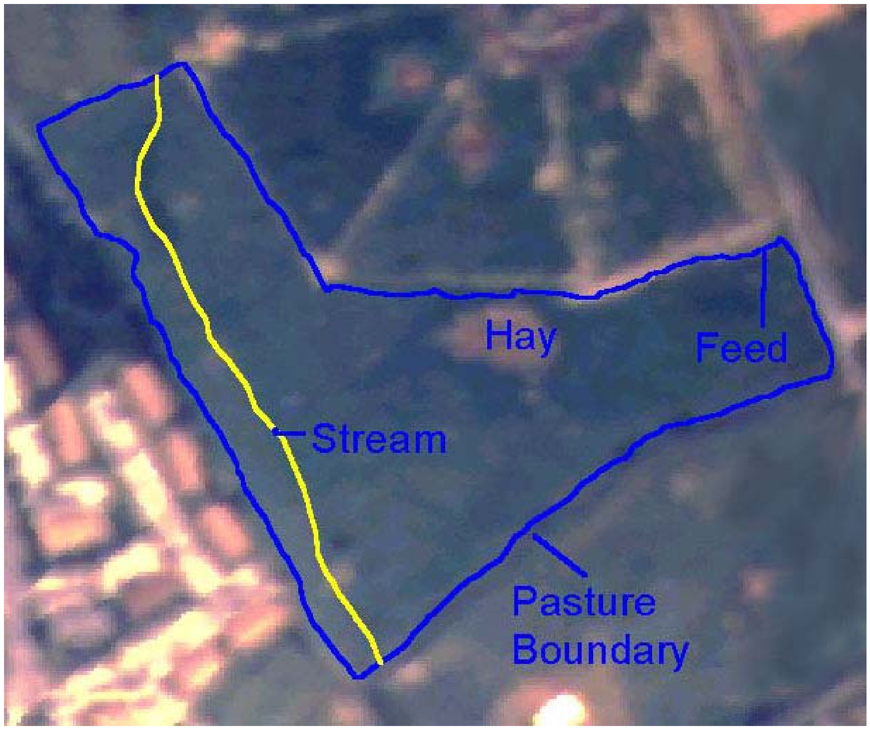

Figure 4-9: Map of Farm D.

Five daily averages during the study period at Farm D are greater than 30 min/cow (Figure 4-10). These days were 11/15/01, 11/16/01, 11/22/01, 11/23/01, and 1/9/02, on which values of 30.25, 30.8, 34.13, 45.75, and 31.66 min/cow, respectively, were recorded. Weather during these days was around the average for the time of year (Table 3-4), with high temperatures of 18.9, 20.6, 15.6, 16.7, and 11.7^{o} C, respectively, although all days were extremely sunny. The lowest two daily values for Farm D were 2.8 and 2.7 min/cow, recorded on 12/11/01 and 12/12/01, respectively. Temperatures were average for the time of year, with high temperatures being 8.9 and 7.2^{o} C; however both days were extremely cloudy and a rainfall of 0.28 and 0.03 cm, respectively, were recorded. Only 27.7% of the total observations for Farm D fell between ± 3 minutes of the site average, which was 12.14 min day^{-1}cow^{-1}.

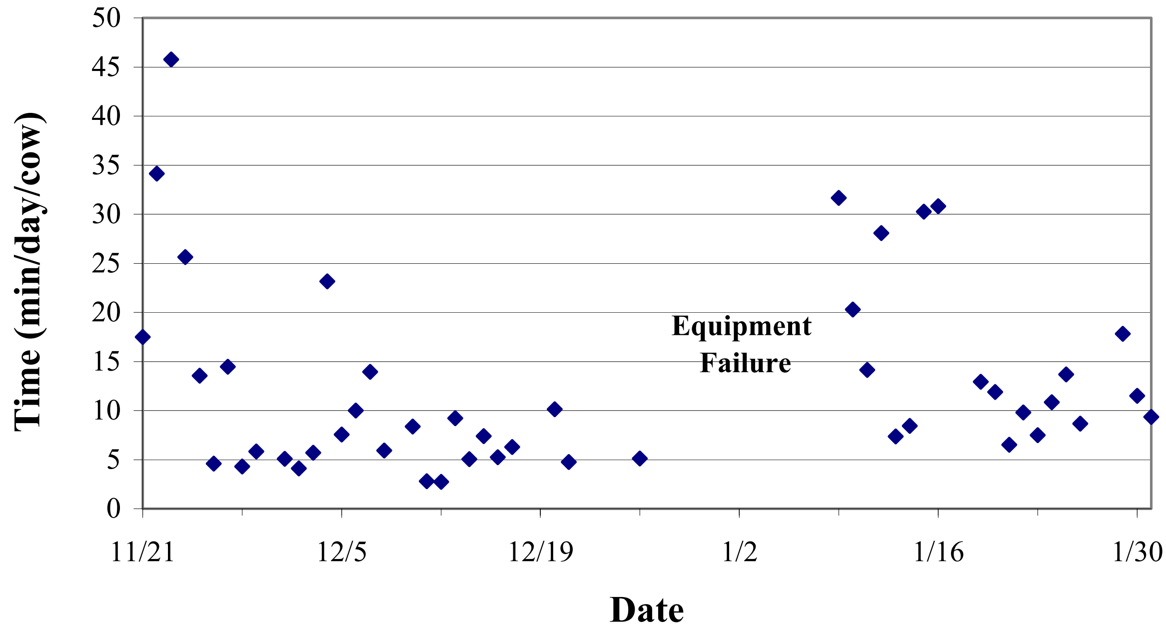

Figure 4-10: Average daily time spent in the stream at Farm D.

Farm D had the highest SD over the study period, 9.49 minutes, and the second-highest average overall daily time spent in the stream, 12.14 min/cow. Most of the cows in the study field at Farm D were black so they may have absorbed more sun, which could have increased water intake needs, the result of higher body temperatures caused by the absorption of more solar radiation. This would in turn increase time spent in streams, but its impact is unknown, and may not be significant since the study period at Farm D took place during colder months.

Difficulty interpreting videos from this farm was encountered because the stream was not well defined, making it difficult to tell if cattle were standing in the stream or next to the stream. The sun setting in the afternoon also shaded the stream and surrounding area considerably, making it difficult to tell exactly where black cows were standing. Both factors introduce the possibility for slight over or under estimation of time in streams.

Farm E

The study period for beef cattle at Farm E lasted 63 days, from 11/28/01 through 1/30/02, during which 26 cow/calf pairs were observed. Only 24 full days were observed during this time, however, due to rotational grazing and VCR malfunctions. The observation period here was split into two periods because the farmer rotationally grazed cattle in two different sections of the study pasture. The first half of the study refers to the time from 11/28/01-1/9/02 when cattle were in the first section of the study pasture, during which 14 days were observed. The second half of the study refers to the time from 1/9/02-1/30/02 when cattle were moved into the second section of the study pasture, during which 10 days were observed. Cows spent an average of 4.15 min $day^{-1}cow^{-1}$ in the stream over the whole study period, having a SD of 2.17 minutes (Table 4-7).

Table 4-7: Summary data for Farm E.

Study Period	Average Time (min $day^{-1}cow^{-1}$)	SD (min)	Range (min $day^{-1}cow^{-1}$)	Average Daily Temp (^oC)	Average Daily Precip (cm)	Number of Days Observed
Overall	4.15	2.17	1.51 – 9.17	3.84	0.218	24
Nov	6.12	3.7	2.0 – 9.17	8.83	0.037	3
Dec	4.59	2.06	1.98 – 8.13	4.39	0.210	11
Jan	3.08	1.2	1.51 – 5.04	2.62	0.226	10

The stream meanders for 670 m through the pasture observed during the first half of the study period, so only a portion of the stream could be videotaped. There is a significant amount of grazing land on both sides of the stream, causing cattle to cross for grazing purposes (Figure 4-11). Cattle did not need to cross the stream to get to feed locations, as was the case on other farms, since no feed or hay was fed during the study.

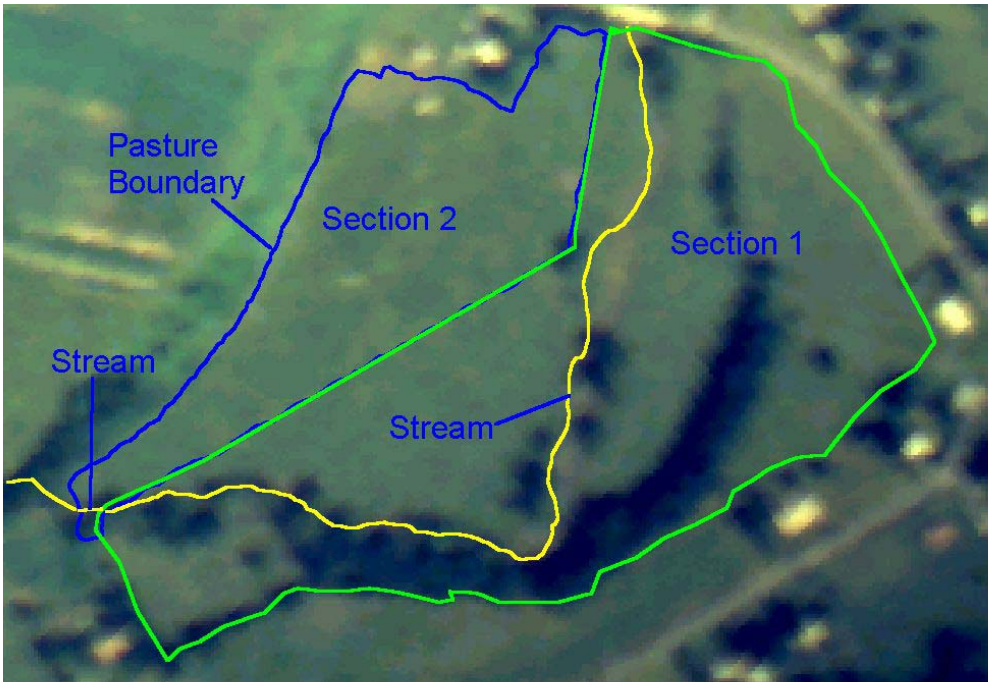

Figure 4-11: Map of Farm E.

The pasture observed during the second half of the study period was considerably smaller than that observed during the first half. The stream for the second half of the study was videotaped in its entirety, since it is only 16 m long in the second pasture section. The stream here is located in one corner of the pasture, requiring cows to travel specifically to the stream in order to drink. Cattle did not need to cross the stream to get to additional sections of the pasture for grazing as they did at other farms. No grain or hay was fed throughout the study in the second study section either.

Two on-site visual observations were conducted during daylight hours for the first half of the study to evaluate the accuracy of interpretation from the videotaped portion of the stream at the first study section. These on-site observations, in conjunction with videotape footage, revealed that cattle were in the videotaped portion of the stream approximately 50% of the time they were present in the stream. This result agreed with average daily times collected during the second half of the study when the entire stream portion was videotaped. As a result, time spent in the stream interpreted from the videotape during the first half of the study was doubled.

Daily time spent in streams at Farm E did not vary as much as it did at other farms. Two observation days during the study period at Farm E had daily times outside the average range for the site. These two days occurred during the first half of the study on 11/28/01 and 12/15/01, on which cows spent 9.17 and 8.13 min/cow, respectively, in the stream (Figure 4-12). The weather on 11/28 was unusually warm for the time of year, with a high temperature of 22.8° C under partly sunny skies, and no rainfall recorded. The weather on 12/15 was average for the time of year, the high temperature being 9.4° C under partly sunny skies.

On three different days, cows spent less than 2 min/cow in the stream on average. These were the low values for the site, occurring 12/1/01, 1/12/02, 1/21/02, with cows spending 1.98, 1.51, and 1.83 min/cow, respectively, in the stream. No rainfall was reported for 12/1 and the high temperature was 18.3° C, which was similar to high temperatures of surrounding days. On 1/12 and 1/21, high temperatures were 8.3 and 9.4° C, respectively, average for the time of year. Light rain, sleet, and light snow were reported for 1/21. At Farm E, 91.7% of the observations occurred within ± 3 minutes of the daily average for this site, which was 4.15 min $day^{-1}cow^{-1}$.

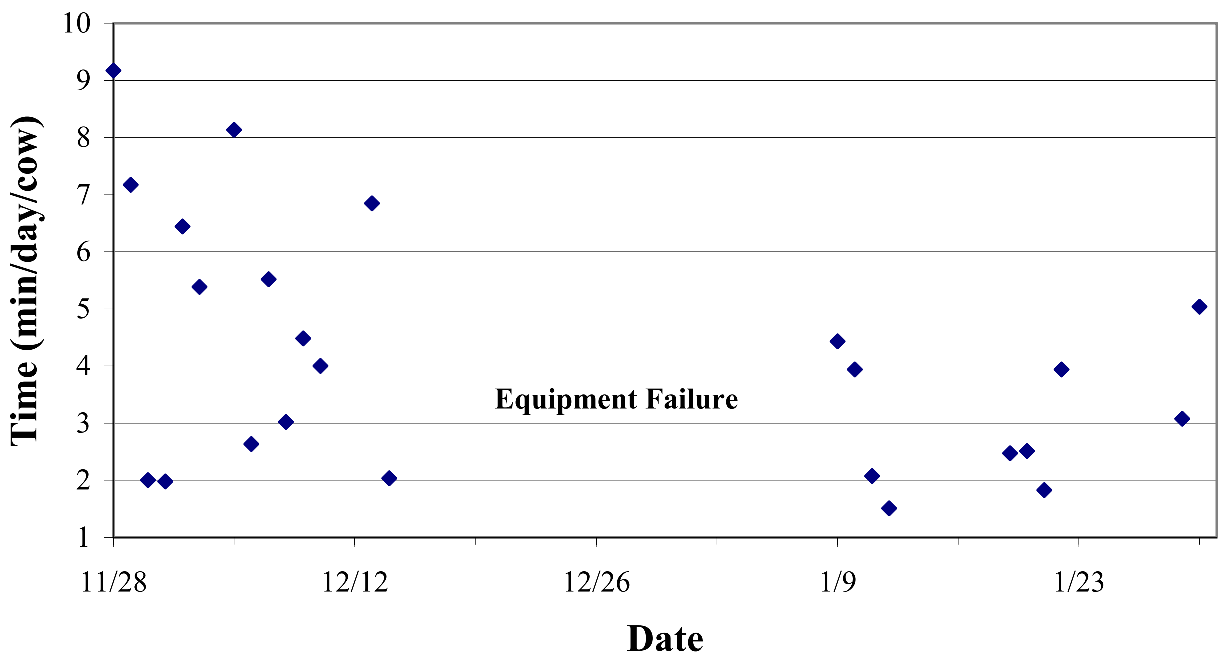

Figure 4-12: Average daily time spent in the stream at Farm E.

Out of the five farms studied, the smallest amount of time spent in streams occurred at Farm E. Here, cattle spent an overall average of 4.15 min $day^{-1}cow^{-1}$ in the stream over the course of the study period (24 days were observed). Farm E also had the smallest SD (2.17

min/day) of all farms studied. Unlike other farms with longer study periods, the study period for Farm E took place in its entirety during the coldest part of the winter, which could have influenced average times.

Effects of Feed Composition

The amount and type of feed eaten by cattle is linked to water intake (Church et al., 1974; Castle and Thomas, 1975; ARC, 1980); therefore, differences in feed composition among farms may have contributed to differences in average daily time spent in streams between farms. Nutrient composition of feed, pasture, and hay were tested on each farm.

Feed

Different types and amounts of feed were fed on three different farms, Farms C, E, and F (Table 4-8). Hay was also fed on these three farms, but hay nutrient composition did not vary greatly between farms during the study. Once again, feed fed at Farm A was only 1.36 kg, so it was considered to be insignificant in affecting water intake and assumed to be zero for model-building purposes.

Table 4-8: Nutrient composition and consumption of feed.

	DM % as fed basis	CP % DM basis	ADF % DM basis	NDF % DM basis	TDN % DM basis	Amount Fed kg/day as fed
Farm B	89	17.8	16.7	43.3	78.45	9.07
Farm C	47.24	14.38	23.18	36.95	69.25	11.34
Farm D	39.23	16.21	27.65	41.85	67.1	8.7

Feed fed at Farm B had the highest concentration of DM, CP, NDF, and TDN. Out of the three farms where feed was fed, Farm B had the lowest average daily time spent in streams, while Farm C had the highest average daily time. For this study, concentrations of nutrients were measured, but total intake of each parameter was not measured due to the difficulty in quantifying pasture intake. Total nutrient intake is dependent on the amount of feed, hay, and pasture consumed at each site.

Research shows cattle consume an average of 2-4 kg water for every kg dry matter consumed (Kay and Hobson, 1963). Past research has shown that overall dry matter intake (DMI) is a better predictor of total water intake than the % DM in feed (Holter and Urban, 1992). Cows at Farm C may have consumed the largest amount of DM, CP, and NDF, since their feeds were higher in those nutrient concentrations, but the total amount consumed was not measured. It would therefore follow that cows at Farm C may have needed to consume more water, and as a result spend more time in the stream.

Pasture

Pasture was analyzed on each farm in order to determine the effect (if any) of its nutrient composition on cattle presence in streams (Table 4-9). Hay was supplemented on Farms B, C, and D starting during the last week of November and the first week of December (varied with farm). Cattle did not stop consuming pasture once hay was available, however they may have consumed greater amounts of hay than forage during this time period; measurements to quantify total consumption of each were not taken.

Table 4-9: Nutrient composition of pasture.

	Month	DM % as fed basis	CP % DM basis	ADF % DM basis	NDF % DM basis	TDN % DM basis
Farm A	October	37.64	15.39	28.84	61.30	69.19
Farm B	November	37.32	14.88	29.79	60.32	68.13
Farm B	December	89.18	11.34	35.71	68.12	61.51
Farm B	January	54.12	13.52	32.24	60.91	65.39
Farm B	February	66.59	12.25	37.12	68.96	59.94
Farm C	November	89.49	8.55	32.11	60.81	65.54
Farm C	December	31.06	11.31	40.65	70.05	55.99
Farm C	January	51.91	13.30	33.42	61.50	64.07
Farm D	December	62.53	12.97	33.75	59.31	63.71
Farm E	December	89.45	10.11	39.88	64.23	56.85
Farm E	January	76.57	9.65	36.47	62.33	60.66

It was difficult to judge the effects of changes in pasture composition on the amount of time cows spent in streams. Some pasture nutrient composition results are missing for some periods on several farms because weather did not allow for sample collection. Samples could not be collected during rainfall events, as this would affect the dry matter content of the pasture. Samples were patted with paper towels in an effort to dry them when collected in the morning or when grass was wet from rain, but this procedure may not have been effective in all cases. This ineffectiveness may explain the low DM content of pasture on Farm C observed during the month of December.

Fescue at Farm E was stockpiled for two months prior to cattle being brought to the study site. This situation meant that there was more pasture at Farm E to be consumed, although it was most likely of a lesser quality than pasture available at other farms during the same time (Ball et al., 1996). Lesser quality in this instance meant that pasture had a higher DM content and a lower CP content. Additionally, cattle were not fed hay or feed at this site as they were on other farms. The lack of hay being fed may have meant that cattle at Farm E might not have consumed as much DM as they consumed on other farms during this time. Previous cattle studies reported that lower DMI resulted in lower water intake (Holter and Urban, 1992; Murphy et al., 1983).

Hay

The result of hay consumption and composition on cattle presence in streams was investigated because hay has a high DM content. MacLusky (1959), Paquay et al. (1970), and Stockdale and King (1983) noted a positive correlation between water intake and dry matter content of diet.

Hay was analyzed from each farm where fed in order to determine the effect (if any) of its nutrient composition on cattle presence in streams (Table 4-10). Hay was fed on Farms B, C, and D, and nutrient composition varied little among farms. As a result, the five hay nutrient composition parameters were replaced with a single hay parameter to indicate the consumption of hay. This hay parameter had a value of either zero or one; a zero indicated that no hay was being fed at that time, while a one indicated that hay was being fed. Cows were offered as much hay as they could eat at each farm; therefore, it was assumed the quantity of hay offered was not important. Cows may have consumed different amounts of hay depending on age, weight, and breed, but the amounts were not measured.

Table 4-10: Nutrient composition of hay.

	DM % as fed basis	CP % DM basis	ADF % DM basis	NDF % DM basis	TDN % DM basis
Farm B	90.59	8.33	43.26	80.29	51.96
Farm C	90.04	7.07	48.75	76.85	54.89
Farm C	90.43	6.6	49.93	81.87	54.55

It was difficult to determine the influence of hay on cattle presence in streams because feed was fed on these farms as well. The effect of feed consumption could not be separated from the effects of hay consumption, but were most likely related in some way.

Effects of Pasture Characteristics

The effect of pasture characteristics such as pasture size and shape, amount and location of shade, and distance to water on cattle presence in streams was evaluated using aerial photography and GPS data in ArcView GIS software (Table 4-11), as previously described in the methodology. Pasture characteristics were then compiled to determine their significance in predicting cattle presence in streams using regression analyses.

Table 4-11: Important pasture characteristics of each study site.

	PA[1]	SL[2]	TS[3]	TSPA[4]	DCS[5]	PASS[6]	PLSS[7]	DHW[8]	DGW[9]	LTW[10]	SDEN[11]
	(ha)	(m)	(ha)	(ha/ha)	(m)	(%)	(%)	(m)	(m)	(m/m)	animal/ha
Farm A	17.28	108	7.09	0.410	0.0	2.06	100	none	803	1.95	1.39
Farm B	5.99	121	2.14	0.357	0.0	0.95	7.4	95	279	2.22	1.53
Farm C	6.81	16.2	0.31	0.046	38.0	0	0	8	52.4	2	3.81
Farm D	6.11	384	.002	0.0002	16.0	0	0	135	304	0.95	5.41
Farm E -1	9.71	670	2.11	0.218	0.0	34.3	50.3	none	none	2.22	5.35
Farm E-2	3.8	16	0.101	0.026	0.0	0.48	100	none	none	4.12	13.66

[1]Pasture area
[2]Stream length
[3]Total shaded area in the pasture
[4]Ratio of total shaded pasture area to total pasture area
[5]Distance from stream to closest shade
[6]Percent of total shaded area that is located around the stream
[7]Percent of total stream length that is shaded
[8]Distance from hay feeding location to stream
[9]Distance from grain feeding location to stream
[10]Length to width ratio of the pasture
[11]Average pasture stocking density (note: stocking densities varied on Farm B and Farm D with regard to date – see farm descriptions)

It is difficult to assess individual impacts of pasture characteristics on cattle presence in streams. This difficulty is mainly the result of numerous factors interacting with one another at the same time. For instance, cows at Farm A had the largest total pasture area, while cows in the second section at Farm E had the smallest total pasture area. A logical connection should exist between pasture sizes and the amount of time cows spend in the stream; more specifically the distance cows must travel for water. This connection could not be made between Farm A (6.27 min $day^{-1}cow^{-1}$ study average) and Farm E-2 (4.15 min $day^{-1}cow^{-1}$ study average), although the pasture size differences were large. Ambient air temperature during observation periods at the two sites were completely different due to season of year, as were stream lengths and shade amounts, making it impossible to single out one parameter which more-directly influenced cattle presence in streams. Cattle presence in streams is more the result of many parameters interacting together, rather than the direct result of one or two parameters.

Predicting Cattle Presence In Streams

The overall goal for this study was to gain a better estimate of the amount of time cows spend in streams. One of the primary objectives for achieving this goal was to generate and evaluate an empirical equation for predicting cattle presence in streams to be used for the TMDL planning process. Important parameters could then be entered into the equation, yielding the amount of time a cow spends in the stream for given conditions.

Model Development

An all possible regression routine in SAS was used to generate the best possible prediction model using a combination of parameters. Not all 33 regressors were included in model subsets generated by SAS because several parameters were highly correlated (ADF and NDF; CP with TDN and DM). The most significant parameters were used in forming all possible regression combinations by SAS, and the remaining parameters were thrown out of the regression procedure by SAS.

Nutrient components for hay (ADF, NDF, CP, DM, TDN) were not included in the final regression analysis because there were not large differences among nutrient composition between farms, which made them insignificant in the regression equation. Cows that were being fed hay, however, were perhaps consuming different concentrations of nutrients than cows that consumed no hay; therefore, a parameter indicating the consumption of hay was included in the regression.

Table 4-12 displays model results from the regression analysis while accounting for daily correlation of measurements on individual farms. These models in Table 4-12 represent the best-possible combination of inputted parameters using one parameter through 14 parameters to predict time in streams. The parameter combinations explain the highest amount of variability among the response variable (amount of time cattle spend in streams), given the specified number of parameters.

Many factors must be considered when selecting a prediction model, and it is often a tradeoff between several factors. The model needs to have enough variables to predict new responses well, but needs to be simple enough so as not to over fit the data. Picking the best-fitting model is often an exchange between choosing the number of parameters to include in the model, and the increase in explained variability the model gives with each additional parameter added. The outcome of this decision in many cases varies from modeler to modeler.

Model #8 from Table 4-12 was chosen as the best model for predicting cattle presence in streams. This model has an R^2 of 0.63 and the lowest AIC value of all model subsets, while using the lowest necessary number of parameters to explain the response well.

$$MDC = 27.937 + 0.157 * maxtemp - 0.189 * mintemp + 0.104 * fdm - 0.372 * fndf - 5.00 * sden$$
$$+ 14.132 * ltw - 63.163 * tspa - 6.106 * hay$$

Where: *MDC* = average daily time in streams (min $day^{-1} cow^{-1}$)
maxtemp = maximum daily temperature (^oC)
mintemp = minimum daily temperature (^oC)
fdm = dry matter content of pasture (% DM basis)
fndf = neutral detergent fiber content of pasture (% DM basis)
sden = pasture stocking density (# animals/ha)
ltw = length to width ratio of the pasture (m/m)
tspa = total shaded area of the pasture (ha)
hay = hay feeding indicator (0 if not being fed or 1 if being fed)

Table 4-12: Model results from the regression analysis.

Model	R^2	AIC	maxtemp	mintemp	precip	wind	rh	fdm	ftdn	fndf	gdm	sden	pass	plss	ts	tspa	pa	dgw	dhw	ltw	hay
1	0.32	1500												X							
2	0.44	1472										X				X					
3	0.46	1470					X					X				X					
4	0.53	1473					X						X					X			X
5	0.59	1437		X								X				X				X	X
6	0.6	1437	X	X								X				X				X	X
7	0.62	1432	X	X				X				X				X				X	X
8	0.63	1430	X	X				X		X		X				X				X	X
9	0.63	1433	X	X			X	X		X		X				X				X	X
10	0.63	1431	X	X	X		X	X		X		X				X				X	X
11	0.64	1442	X	X	X		X	X	X			X					X		X	X	X
12	0.64	1442	X	X	X		X	X	X	X		X		X	X		X				X
13	0.64	1445	X	X	X	X	X	X	X	X		X		X	X		X				X
14	0.64	1446	X	X	X	X	X	X	X	X	X	X					X	X		X	X

An X marks the inclusion of that regressor in the model.

Parameters included in the final prediction model are a combination of feed, climatic, and pasture characteristics. Individual parameters included in the prediction model interact with one another to influence the response as a whole, and not independently. Model parameters are in different units, making it impractical to discuss the magnitudes of these parameter coefficients. The impact on the amount of time cows spend in streams, however, can be discussed by comparing the signs of these parameter coefficients.

The only two climatic parameters included in the selected model are maximum and minimum daily temperature. As expected, relationships indicate an increase in maximum daily temperature increases the amount of time cows spend in streams when all other variables are held constant. The relationship between the minimum daily temperature and the amount of time cows spend in streams is not as clear. The model indicates that minimum daily temperature and the amount of time cows spend in streams are inversely related looking at the negative parameter coefficient. This presents a dilemma, however, because although minimum temperature overall decreases the amount of time cows spend in streams, higher minimum daily temperatures entered into the model decrease time in streams compared to lower minimum daily temperature values entered into the model.

The total shaded area of the pasture has an expected negative relationship to the amount of time cows spend in streams. It was theorized that cows in a pasture with a large amount of shade would stay cooler, and as a result spend less time in streams. The relationship from the model between shaded area and time cows spend in streams indicates that a greater amount of shade in pastures decreases the amounts of time cows spend in streams when all other variables are held constant. Observations were conducted during cooler seasons of the year; therefore the effect of shade during warmer months may differ from observed effects.

The model indicates a negative relationship between cows consuming hay and how much time they spend in streams; cows consuming hay spend less time in streams according to the model. It was theorized that cows consuming hay might have increased water needs due to the nutrient composition and high dry matter content of hay. Model results indicate that this is not the case, however, and that cattle consuming hay may spend less time in streams. According to the model, dry matter content of pasture has a positive effect on the amount of time cows spend in streams, while neutral detergent fiber content has a negative effect.

The stocking density of the pasture has a negative effect on the amount of time cows spend in streams when other variables are held constant. The length to width ratio of the pasture has a positive effect on cattle presence in streams according to the model. This ratio is an indicator of pasture size and shape, and is a measure of the distance cows must travel to reach the stream.

Model Evaluation

The prediction model was evaluated to determine its effectiveness at predicting cattle presence in streams. Model evaluation was first conducted using data from Farm D, none of which was used in developing the model. Daily parameters from Farm D were inputted into the model and daily predicted time in streams were calculated and compared to measured daily observed time in streams. Table 4-13 gives monthly summaries of daily inputted model parameters and compares calculated daily predicted values to observed daily values averaged by month.

The model predicted average values for November and December far below observed monthly average values for November and December. This underestimation was possibly due to the high stocking density of the pasture at Farm D during those months compared to the stocking densities of Farms A, B, C, and E whose data were used to develop the model. Stocking densities on Farms A, B, C, and E on average ranged between 1-4 animals/ha, which was much lower than the stocking density of Farm D during November and December (8.5 animals/ha). The average predicted amount of time in streams at Farm D for January was much closer to the observed average value for January when the stocking density of the pasture decreased to 1.3 animals/ha.

Model evaluation conclusions reached using data from Farm D may also have been poor due to a possible abnormality of data from Farm D. When statistical analysis began, data from Farm D were added to data from other farms during the model-building process. When data from Farm D were removed from the model-building process, the variation explained by the model increased by 20%, indicating a possible abnormality of data from Farm D. This abnormality of data from Farm D may be the result of video interpretation from the site. The stream section flowing through Farm D was not well defined, making it difficult sometimes to

Table 4-13: Model evaluation results from Farm D.

Month	Observed MDC[1]	Predicted MDC[2]	√Residual	maxtemp[3]	mintemp[4]	fdm[5]	fndf[6]	sden[7]	ltw[8]	tspa[9]	hay[10]
Nov	12.22	-20.39	32.6	18.41	1.83	62.53	59.31	8.51	0.95	0	1
Dec	7.67	-21.12	28.8	12.35	0.69	62.53	59.31	8.51	0.95	0	1
Jan	13.8	15.09	1.3	11.32	-1.55	62.53	59.31	1.33	0.95	0	1

Table 4-14: Model evaluation results from Farms A, B, C, and E.

Farm	Observed MDC[1]	Predicted MDC[2]	√Residual	maxtemp[3]	mintemp[4]	fdm[5]	fndf[6]	sden[7]	ltw[8]	tspa[9]	hay[10]
A	5.27	5.73	0.5	22.39	7.95	37.64	61.3	1.39	1.95	0.41	0
B	9.80	8.50	1.3	8.10	-4.33	67.3	65.0	1.67	2.22	0.36	0.79*
C	16.54	15.48	1.1	11.32	0.56	63.7	61.3	3.81	2.00	0.05	0.69*
E	3.40	5.08	1.7	16.59	3.97	85.8	63.7	7.73	2.76	0.16	0

[1]Observed daily time spent in streams (min $day^{-1}cow^{-1}$)
[2]Model predicted time spent in streams (min $day^{-1}cow^{-1}$)
[3]Average maximum daily temperature (^oC)
[4]Average minimum daily temperature (^oC)
[5]Average dry matter content of pasture (% as fed basis)
[6]Average neutral detergent fiber content of pasture (% DM basis)
[7]Average pasture stocking density (# animals/ha)
[8]Length to width ratio of the pasture (m/m)
[9]Total shaded area of the pasture (ha)
[10]Hay feeding indicator (either 0 or 1)

differentiate between cows standing in or beside the stream, as previously discussed with earlier results from Farm D.

A second model evaluation was conducted due to the inadequateness of evaluation results using data from Farm D. For this second evaluation, 50 days of data were randomly selected from the dataset containing data for all farms (excluding Farm D). Predicted daily time in streams were then calculated for each of the 50 observation days using the model, and compared to measured observed values. Table 4-14 gives average values for inputted daily model parameters, observed daily time in streams, and predicted daily time in streams averaged by farm from the 50 randomly chosen evaluation days.

The second model evaluation procedure yielded much better evaluation results, as evidenced by the square root of the residuals from the first and second evaluation procedures (Tables 4-13 and 4-14). It must be taken into consideration that the evaluation set used for the second model evaluation procedure was randomly selected from the 250 observations used to build the model. Results of the second evaluation indicate predicted daily time in streams varied approximately ±1.5 min $day^{-1}cow^{-1}$ from observed average daily time in streams for all four farms.

Model Limitations

The prediction model was built using data collected mostly during fall and winter months. No warm weather data was available to evaluate the effectiveness of the model at predicting average daily time in streams during warmer months. The model will most likely not be effective at predicting cattle presence in streams during warmer summer months, since it was built using cool season data. For this reason, the model should not be used for predicting the amount of time cows spend in streams during summer months.

Another limitation of the model is that it may not accurately predict the amount of time spent in streams by lactating dairy cows when streams are their sole water source. Although many comparisons are often made between housed and grazed cattle, MacLusky (1959) and Stockdale and King (1983) do not believe equations predicting water intake of housed cows can be applied to those on pasture, primarily due to differences in environment and diet.

The data used to build the prediction model were from non-lactating beef and dairy cattle, which have a different water requirement from lactating cows. Milk is 87% water by weight;

therefore lactating cows need to drink 1.5-2.2 times the amount of water that nonlactating cows drink (Winchester and Morris, 1956). One of the primary reasons cattle stand in streams is to drink; therefore lactating cows consuming all of their water solely from streams may stand in streams more than nonlactating cows because they have higher water requirements.

Management practices are often considerably different for lactating dairy cows than for nonlactating beef and dairy cattle, which may also contribute to model limitations. Not only do nutrient requirements of milking cows differ, but milking cows are also often confined for the majority of the day, generally during hotter portions. Milk cows' drinking schedules often coincide with when they are milked, which typically occurs twice a day; once in the early morning and once in the early afternoon. These differing conditions might also contribute to a lack of model-effectiveness at predicting cattle presence in streams for lactating dairy cows.

Model Comparison With Past Research

Animal behavior is difficult to predict, and cattle drinking behavior is no exception. This uncertainty and unpredictability is magnified in a field setting where not all variables can be measured and controlled in an ideal manner. Farms have many different variables that interact with one another, making it difficult to isolate the contributions of individual variables. In a laboratory setting where parameters can be monitored and controlled more precisely, regressions generally yield an R^2 well above 0.9, accounting for 90% or more of the variation among the predicted responses. Regressions explaining 50% of the variability of the response, however, is oftentimes considered a success in field research, especially when dealing with animal behavior (O. Schabenberger, personal communication, April 2002, Blacksburg, Virginia).

Animal behavior is difficult to quantify due to its high variability. Animal behavior fluctuates greatly under similar conditions, and increases when conditions vary with study locations. Paquay et al. (1970) noted large differences in water intakes of 100 lactating and non-lactating dairy cows receiving the same diet under the similar management conditions.

There is a lack of research on the amount of time cows spend in streams. Study results were therefore compared to results from previous water intake behavioral studies. Cows drink from streams when streams provide their only source of water; therefore water intake studies give some foundation for how much time cows stand in streams. It must be noted, however, that cattle additionally visit streams for loafing and cooling purposes.

Several researchers have attempted to quantify cattle drinking behavior using linear regressions. Murphy et al. (1983) obtained an $R^2 = 0.42$ when milk production and DMI were used to predict water intake. Castle and Thomas (1975) discovered a positive relationship between DM content of diet, milk production, and water intake of cattle; as DM content of feed and milk production increase, water intake increases. Holter and Urban (1992) developed a water intake prediction equation using DM content of feed, DMI, and CP content in feed, obtaining an $R^2 = 0.64$. They also predicted free water intake in lactating cows using only % DM content of food and got an $R^2 = 0.19$ (Holter and Urban, 1992). The behavior variations explained by these models are similar to variation encountered during model development for the amount of time cows spend in streams.

Effect of Study Results On TMDL Planning

Results from this project should have an effect on TMDL planning, decreasing the variability of the amount of time cattle spend in streams, which is an important factor in TMDL plans. This factor is important to consider during TMDL planning since cattle defecate in streams a large portion of the time they are standing there, which is a direct contribution to fecal coliform loadings. Observers have noted that 6.7-10.5% of the time cattle defecate they do so directly in the stream, usually shortly after drinking (Gary et al., 1983). Direct fecal coliform loadings to streams are important to consider because bacteria do not die-off as significantly as they do when transported to streams through overland flow.

Table 4-15 below displays the amount of time cows were modeled to spend in streams (min $day^{-1}cow^{-1}$) for seven different TMDL plans completed for water bodies in Virginia during 2000-2001, compared to study results. Study results presented are an average of all five farms studied. Also presented in parentheses in Table 4-15 are the numbers of days contributing to monthly study averages for comparison purposes. Most TMDL plans in Table 4-15 were developed based on five-year climate and land-use data, while study averages were obtained with limited data collected over seven months.

Once again, equipment necessary for recording at night was beyond the project budget; therefore streams were only videotaped during daylight hours. Study results presented in Table 4-15 represent average time spent in streams during daylight hours, which was assumed to be the total amount of time spent in streams for the entire day. It is assumed that no cows are present in streams throughout the night.

The amount of fecal coliform deposited in streams is modeled as a direct loading of a nonpoint source. Cattle defecate directly into streams, but the exact amount of fecal coliform and loading locations are not defined as they are for allocated point sources. Most TMDLs assume that 30% of cattle in and around streams defecate in the streams. In the Dry River TMDL, direct deposition of cattle manure into streams accounted for 36% of the mean daily fecal coliform concentration in the streams (Biological Systems Engineering and Biology Departments, 2000).

Beef cattle produce an average of 18,144 g/AU (grams per animal unit) of feces per day, while dairy cows produce an average of 27,216 g/AU (ASAE, 1998). With this, beef cattle produce an average of 20,740 FCx10^6/AU each day, while dairy cows produce a daily average of 31,110 FCx10^6/AU. In the Dry River TMDL, average daily fecal coliform loading to the Dry River from direct deposition by cows was calculated as 298.0x10^9 cfu (Biological Systems Engineering and Biology Departments, 2000). Direct deposition of feces in streams is especially important during low-flow conditions because this increases fecal coliform concentrations.

Previous numbers indicate a large amount of fecal coliform is deposited by cows when standing in streams, but the exact sensitivity of models to the amount of time cattle spend in streams is unknown. Most TMDL planners have discovered that completely removing cows from streams enables waterbodies to meet standards for the geometric mean more often than removing primarily urban or agricultural runoff. This result indicates that models are considerably influenced by the amount of time cows spend in streams, and as a result direct fecal coliform loadings to streams.

The sensitivity of models commonly used for TMDL planning to the amount of time cows spend in streams was not evaluated as part of this project. A difference does exist between time modeled in past studies and results from this study (Table 4-15), but the exact impact on how much it will impact fecal coliform loadings to water bodies and altar TMDL plans in the future is unknown at this time.

Table 4-15: Average time in streams (min $cow^{-1}day^{-1}$) used in TMDL plans and study results.

Month	Cedar Creek[1]	Hutton Creek[2]	Dry River[3]	Mill Creek[4]	Mountain Run[5]	Upper Blackwater[6]	Big Otter[7]	Study Results (days observed)
January	2.12	5.22	30	30	0	30	21	11.5 (81 days)
February	2.11	3.12	30	30	0	30	21	9.7 (56 days)
March	2.11	3.01	45	30	60	60	31.5	Not observed
April	2.11	2.73	60	45	120	90	31.5	Not observed
May	2.11	3.51	90	60	120	90	42	Not observed
June	2.12	3.04	210	210	240	120	84	Not observed
July	2.12	3.12	210	210	240	120	84	Not observed
August	2.11	3.19	210	210	240	120	84	3.7 (10 days)
September	2.11	3.28	90	60	120	90	42	3.8 (21 days)
October	2.11	3.39	60	45	120	60	31.5	9.4 (21 days)
November	2.11	3.36	45	30	60	60	21	14.3 (66 days)
December	2.12	3.95	30	30	0	30	21	7.7 (63 days)

[*] CH2MHill modeled time spent in stream differently for beef cows, dairy cows, and dairy heifers. The sum of all three is presented in this table.

[1] CH2MHILL (2000)
[2] CH2MHILL (2000)
[3] Biological Systems Engineering and Biology Departments (2000)
[4] Biological Systems Engineering and Biology Departments (2000)
[5] Yagow (2001)
[6] MapTech, Inc. (2000)
[7] Biological Systems Engineering and Biology Departments (2000)

Chapter 5 : Summary and Conclusions

The amount of time cattle spend standing in streams is one input parameter used in computer models when total maximum daily load (TMDL) plans are being made. This input parameter is estimated using professionals' best judgment, since experimental data are not available, and estimations are inconsistent. The overall goal of this study was to gain a better estimate of the amount of time cattle spend in streams, since this has a significant impact on the amount of fecal coliform directly deposited in streams. Significant factors influencing the amount of time cattle spend in streams were identified, and an equation predicting the amount of time cattle spend in streams was then generated.

Five farms were studied in southwest Virginia from August 2001 through February 2002. Camera surveillance systems were set up on two beef farms and three dairy heifer operations to monitor cattle stream activity during daylight hours. Climatic data, pasture characteristics, feed characteristics, and farm management practices were collected from each site, and their relationships between the amount of time cattle spend in streams were investigated.

No significant difference ($p=0.82$) was found between the amount of time beef cattle spent in streams and the amount of time dairy heifers spent in streams. Overall, cows spent an average of 10.12 min $day^{-1}cow^{-1}$ standing in streams, and spent the highest amount of time in streams during the month of November (14.3 min $day^{-1}cow^{-1}$).

A combination of daily temperatures, feed composition, and pasture characteristics were found to significantly affect cattle presence in streams. More specifically, significant factors influencing the amount of time cows spend in streams include: maximum daily temperature, minimum daily temperature, the consumption of hay, dry matter fiber content of pasture, neutral detergent fiber content of pasture, stocking density of the pasture, total shaded pasture area, and the length to width ratio of the pasture. These significant factors were included in a prediction equation, which yielded an estimated R^2 value of 0.63. This equation is somewhat limited in its application. It may not accurately predict the amount of time spent in streams by cows during warmer summer months, since data was collected during fall and winter months. Other limitations may be encountered when using the model to predict the amount of time lactating dairy cows spend in streams when streams are their sole water source, since they have a much higher water requirement than those cows studied.

The equation's performance at predicting new responses was evaluated and also compared to results from past animal behavioral studies. Results from previous research on water intake of cattle are similar to results obtained from this research when comparing R^2 values. The factors that researchers discovered impacted water intake of cows are also similar to factors that were found to contribute to cattle presence in streams for this study. In conclusion, study results indicate that cattle spend a different amount of time standing in streams than the amount of time modeled in previous TMDL plans, which may have the potential to impact future TMDL plans.

Recommendations For Future Study

Several recommendations can be made for the continuation of research in the area of cattle stream behavior prediction. The most important suggestion is to continue monitoring during summer months in order to validate the effect of temperature on cattle presence in streams. As discussed previously, there is most likely limited accuracy when predicting cattle presence in streams during summer months based on data collected during winter months. After a year of monitoring on several different farms, variations in seasonal trends should be investigated. These seasonal trends will most likely lend themselves to the development of different prediction equations for each season, increasing prediction accuracy.

The impact of solar radiation on cattle stream presence was not assessed for this project due problems with data collection; however, its importance on cattle presence in streams should be investigated. Lastly, multiple direct nighttime observations should be conducted at farms to assess the validity of assuming cattle are present in streams only during daylight hours.

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Appendix A

Table 0-1: Data used in regression analysis.

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
8/16/01	1	A	4.92	27.78	16.67	22.22	0	4.99	78	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/17/01	2	A	5.17	27.22	17.22	22.22	0	2.74	82	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/18/01	3	A	3.94	27.22	16.11	21.67	0	2.74	74	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/19/01	4	A	5.31	27.22	17.78	22.78	0.610	5.15	79	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/21/01	6	A	6.63	25.00	10.56	17.78	0	4.83	74	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/22/01	7	A	2.73	26.11	10.00	18.33	0	3.54	76	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/23/01	8	A	2.48	28.89	14.44	21.67	1.041	5.47	78	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/27/01	12	A	2.38	27.22	15.56	21.67	0.254	2.74	81	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/28/01	13	A	0.00	27.22	17.22	22.22	0	4.99	78	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
8/31/01	16	A	3.94	24.44	15.00	20.00	0.051	6.44	85	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/1/01	17	A	0.13	27.22	17.78	22.78	1.194	3.54	81	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/2/01	18	A	1.56	25.00	15.56	20.56	0	7.40	82	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/3/01	19	A	0.00	19.44	17.78	18.89	0.023	4.18	87	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/4/01	20	A	2.96	27.22	14.44	21.11	0	4.02	81	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/5/01	21	A	0.93	27.78	13.89	21.11	0	2.25	76	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/6/01	22	A	5.20	26.67	16.11	21.67	0	4.67	76	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/7/01	23	A	5.29	28.33	15.56	22.22	0	4.18	78	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/8/01	24	A	1.69	27.78	12.22	20.00	0	4.99	74	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/9/01	25	A	4.10	27.78	12.22	20.00	0	7.08	79	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/10/01	26	A	5.04	25.56	13.33	19.44	0.023	5.31	84	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/11/01	27	A	4.17	25.56	8.89	17.22	0	2.09	68	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/12/01	28	A	5.81	25.56	8.33	17.22	0	4.18	73	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/13/01	29	A	9.80	27.22	8.89	18.33	0	1.45	73	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/14/01	30	A	3.67	18.89	7.22	13.33	0.076	6.12	86	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/15/01	31	A	9.94	20.56	3.89	12.22	0	5.95	69	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/24/01	40	A	0.00	17.78	10.00	13.89	1.702	6.28	91	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/25/01	41	A	2.79	12.78	3.89	8.33	0	13.04	74	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
9/26/01	42	A	6.29	16.67	2.22	9.44	0	9.33	70	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
8/16/01	1	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/17/01	2	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/18/01	3	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/19/01	4	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/21/01	6	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/22/01	7	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/23/01	8	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/27/01	12	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/28/01	13	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
8/31/01	16	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/1/01	17	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/2/01	18	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/3/01	19	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/4/01	20	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/5/01	21	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/6/01	22	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/7/01	23	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/8/01	24	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/9/01	25	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/10/01	26	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/11/01	27	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/12/01	28	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/13/01	29	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/14/01	30	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/15/01	31	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/24/01	40	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/25/01	41	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/26/01	42	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/27/01	43	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
9/28/01	44	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
9/29/01	45	A	3.17	17.78	3.33	10.56	0	7.08	76	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/1/01	47	A	4.69	20.56	2.78	11.67	0	10.94	68	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/2/01	48	A	10.33	23.89	11.11	17.78	0	7.24	73	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/3/01	49	A	11.54	25.00	6.11	15.56	0	3.38	72	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/4/01	50	A	6.83	23.89	5.56	15.00	0	4.02	69	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/5/01	51	A	20.06	24.44	5.00	15.00	0	7.24	70	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/6/01	52	A	7.13	17.78	2.78	10.56	0.229	13.36	73	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/7/01	53	A	13.81	12.78	2.22	7.78	0	10.94	56	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/8/01	54	A	5.54	15.56	-3.89	6.11	0	2.09	68	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/9/01	55	A	30.67	17.22	-2.22	7.78	0	4.83	60	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/10/01	56	A	7.67	20.56	-1.11	10.00	0	2.90	72	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/11/01	57	A	9.79	23.33	4.44	13.89	0	3.54	73	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/16/01	62	A	7.75	17.78	2.78	10.56	0.023	15.77	68	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/17/01	63	A	4.52	8.89	2.22	5.56	0	17.54	64	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/18/01	64	A	8.83	16.67	-2.78	7.22	0	1.61	61	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/19/01	65	A	8.10	19.44	-2.78	8.33	0	2.57	59	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/25/01	71	A	3.92	21.11	9.44	15.56	0.279	22.85	58	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/26/01	72	A	5.21	10.56	1.67	6.11	0.023	25.91	46	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/27/01	73	A	2.52	2.78	-1.11	1.11	0.023	17.38	64	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/28/01	74	A	10.35	10.00	-5.56	2.22	0	5.95	62	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/30/01	76	A	5.58	20.56	-2.78	8.89	0	2.09	54	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/3/01	80	A	4.46	20.00	3.89	12.22	0	8.53	66	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/4/01	81	A	6.23	18.33	-1.67	8.33	0	5.15	60	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/5/01	82	A	4.13	13.33	0.00	6.67	0	14.16	47	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/6/01	83	A	7.65	15.56	-1.11	7.22	0	8.69	47	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/7/01	84	A	7.10	19.44	-0.56	9.44	0	6.60	42	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/8/01	85	A	9.15	21.67	-3.33	9.44	0	5.47	53	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/9/01	86	A	12.08	14.44	-1.11	6.67	0	12.39	50	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/10/01	87	A	7.69	19.44	-5.00	7.22	0	8.69	53	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
11/11/01	88	A	12.00	13.33	-2.78	5.56	0	13.20	63	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
9/29/01	45	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/1/01	47	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/2/01	48	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/3/01	49	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/4/01	50	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/5/01	51	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/6/01	52	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/7/01	53	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/8/01	54	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/9/01	55	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/10/01	56	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/11/01	57	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/16/01	62	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/17/01	63	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/18/01	64	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/19/01	65	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/25/01	71	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/26/01	72	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/27/01	73	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/28/01	74	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/30/01	76	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/3/01	80	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/4/01	81	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/5/01	82	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/6/01	83	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/7/01	84	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/8/01	85	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/9/01	86	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/10/01	87	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
11/11/01	88	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
11/12/01	89	A	9.21	14.44	-6.67	3.89	0	0.80	64	37.64	15.39	28.84	61.30	69.19	0	0	0	0	0
10/31/01	77	B	13.00	19.44	-1.11	9.44	0	3.22	58	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/1/01	78	B	34.71	21.11	-0.56	10.56	0	4.35	67	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/2/01	79	B	17.43	23.33	5.56	14.44	0	3.54	71	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/3/01	80	B	17.00	20.00	3.89	12.22	0	8.53	66	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/4/01	81	B	13.00	18.33	-1.67	8.33	0	5.15	60	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/5/01	82	B	8.57	13.33	0.00	6.67	0	14.16	47	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/6/01	83	B	16.71	15.56	-1.11	7.22	0	8.69	47	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/7/01	84	B	11.14	19.44	-0.56	9.44	0	6.60	42	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/8/01	85	B	11.29	21.67	-3.33	9.44	0	5.47	53	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/9/01	86	B	18.00	14.44	-1.11	6.67	0	12.39	50	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/10/01	87	B	15.00	19.44	-5.00	7.22	0	8.69	53	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/11/01	88	B	7.57	13.33	-2.78	5.56	0	13.20	63	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/12/01	89	B	9.71	14.44	-6.67	3.89	0	0.80	64	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/13/01	90	B	6.00	14.44	-6.11	4.44	0	3.54	61	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/14/01	91	B	13.86	17.22	-6.67	5.56	0	0.48	66	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/15/01	92	B	30.43	18.89	-4.44	7.22	0	1.29	64	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/16/01	93	B	8.31	20.56	-1.67	9.44	0	5.47	65	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/17/01	94	B	6.46	20.56	0.56	10.56	0	3.70	64	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/18/01	95	B	11.38	18.89	0.00	9.44	0	1.93	74	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/19/01	96	B	8.77	18.33	-1.11	8.89	0	4.67	73	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/20/01	97	B	10.31	12.22	-2.78	5.00	0	13.68	61	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/21/01	98	B	18.54	11.11	-5.00	3.33	0	1.45	60	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/22/01	99	B	8.69	15.56	-5.56	5.00	0	2.09	56	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/24/01	101	B	7.00	12.22	7.22	10.00	0.330	9.33	97	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/25/01	102	B	4.08	19.44	3.89	11.67	0.660	9.66	84	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/26/01	103	B	3.23	19.44	1.11	10.56	0	0.48	75	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/27/01	104	B	4.31	22.78	3.89	13.33	0	2.41	79	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/28/01	105	B	5.23	22.78	6.11	14.44	0	4.02	75	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/29/01	106	B	4.77	17.78	8.33	13.33	0.023	8.53	80	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96
11/30/01	107	B	5.31	19.44	10.56	15.00	0.023	14.32	81	37.32	14.88	29.79	60.32	68.13	90.59	8.33	43.26	80.29	51.96

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
11/12/01	89	A	0	0	0	0	0	7.09	2.06	100	24	1.39	17.29	0	803	1.95	108	0.410	0	0
10/31/01	77	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/1/01	78	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/2/01	79	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/3/01	80	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/4/01	81	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/5/01	82	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/6/01	83	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	7	1.17	5.99	95	279	2.22	121	0.357	0	0
11/7/01	84	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/8/01	85	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/9/01	86	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/10/01	87	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/11/01	88	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/12/01	89	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/13/01	90	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/14/01	91	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/15/01	92	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/16/01	93	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/17/01	94	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/18/01	95	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/19/01	96	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/20/01	97	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/21/01	98	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/22/01	99	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/24/01	101	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/25/01	102	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/26/01	103	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/27/01	104	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/28/01	105	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/29/01	106	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	0
11/30/01	107	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
12/7/01	114	B	4.85	14.44	8.89	11.67	0.023	5.47	84	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/8/01	115	B	5.96	10.56	6.67	8.89	0.178	6.60	93	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/9/01	116	B	6.12	12.22	1.67	7.22	0	14.16	67	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/10/01	117	B	5.06	3.33	-2.22	0.56	3.378	4.51	88	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/11/01	118	B	1.96	8.89	2.22	5.56	0.279	4.35	96	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/12/01	119	B	2.31	7.22	5.56	6.67	0.025	9.82	96	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/13/01	120	B	2.58	14.44	6.11	10.56	0.229	2.41	94	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/14/01	121	B	4.62	13.89	8.89	13.89	0	11.75	78	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/15/01	122	B	4.58	9.44	0.00	5.00	0	11.59	78	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/16/01	123	B	8.65	10.00	-1.67	4.44	0	3.22	77	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/17/01	124	B	3.88	12.22	-0.56	6.11	0.787	4.83	88	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/19/01	126	B	4.23	12.22	-4.44	3.89	0.023	7.40	74	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/20/01	127	B	4.00	6.11	-3.33	1.67	0	22.53	55	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/21/01	128	B	5.04	5.56	-3.33	1.11	0	14.32	53	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/23/01	1	B	6.77	8.89	-5.00	2.22	0.330	6.92	82	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/24/01	130	B	6.96	5.56	-3.33	1.11	0	15.93	65	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/25/01	131	B	7.50	3.33	-8.89	-2.78	0	6.28	55	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/26/01	132	B	8.04	0.56	-7.78	-3.33	0	9.49	61	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/27/01	133	B	7.35	0.00	-5.56	-2.78	0.023	17.22	59	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/28/01	134	B	6.73	6.11	-5.00	0.56	0	14.97	70	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/29/01	135	B	6.08	6.67	-6.67	0.00	0.023	16.90	71	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/30/01	136	B	6.69	-1.67	-8.89	-5.00	0.023	18.35	57	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
12/31/01	137	B	4.96	-1.67	-10.56	-6.11	0	13.20	63	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
1/1/02	138	B	6.54	-1.67	-12.78	-7.22	0.023	9.66	60	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
1/2/02	139	B	11.75	-2.78	-14.44	-8.33	0	1.29	71	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
1/3/02	140	B	11.42	-2.78	-6.67	-4.44	0.025	9.66	68	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
1/5/02	142	B	16.25	7.78	-8.33	0.00	0	5.95	48	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
1/6/02	143	B	9.33	1.11	-7.78	-3.33	0.559	7.08	80	89.18	11.34	35.71	68.12	61.51	90.59	8.33	43.26	80.29	51.96
1/7/02	144	B	6.42	0.00	-6.11	-2.78	0.023	21.24	79	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/8/02	145	B	11.08	2.78	-6.67	-1.67	0.023	14.48	59	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
12/7/01	114	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/8/01	115	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/9/01	116	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/10/01	117	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/11/01	118	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/12/01	119	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/13/01	120	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/14/01	121	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/15/01	122	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/16/01	123	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/17/01	124	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/19/01	126	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/20/01	127	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/21/01	128	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/23/01	1	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/24/01	130	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/25/01	131	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/26/01	132	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/27/01	133	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/28/01	134	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/29/01	135	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/30/01	136	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
12/31/01	137	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
1/1/02	138	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
1/2/02	139	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	13	2.17	5.99	95	279	2.22	121	0.357	0	1
1/3/02	140	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/5/02	142	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/6/02	143	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/7/02	144	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/8/02	145	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
1/9/02	146	B	6.83	11.67	-2.78	4.44	0	16.74	57	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/10/02	147	B	12.17	14.44	4.44	9.44	0	14.48	73	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/11/02	148	B	8.08	11.11	-0.56	5.56	0.102	20.60	71	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/12/02	149	B	13.83	8.33	-6.11	1.11	0	7.40	69	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/13/02	150	B	14.08	6.11	-1.11	2.78	0.023	19.15	56	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/14/02	151	B	11.33	8.33	-7.78	0.56	0	6.44	67	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/15/02	152	B	10.50	7.78	-3.33	2.22	0	20.44	70	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/16/02	153	B	10.92	7.78	-3.89	2.22	0	6.76	55	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/17/02	154	B	14.83	11.11	-3.33	3.89	0	10.78	57	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/18/02	155	B	9.00	3.89	-6.67	-1.11	0.023	12.55	58	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/19/02	156	B	8.83	0.56	-4.44	-1.67	1.829	7.08	79	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/20/02	157	B	13.33	3.33	-3.89	0.00	0.023	6.60	78	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/21/02	158	B	8.17	9.44	-2.78	3.33	0.076	11.59	73	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/22/02	159	B	9.83	11.67	-3.33	4.44	0	7.40	53	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/23/02	160	B	1.42	12.78	1.11	7.22	1.930	1.45	81	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/24/02	161	B	2.92	13.33	6.11	10.00	0.914	9.98	90	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/25/02	162	B	7.42	8.89	-5.00	2.22	0	9.82	65	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/26/02	163	B	6.00	14.44	-8.33	3.33	0	2.41	67	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/27/02	164	B	14.00	17.78	-7.22	5.56	0	2.25	61	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/28/02	165	B	11.46	18.89	-4.44	7.22	0	1.77	68	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/29/02	166	B	11.46	18.33	0.56	9.44	0	6.76	81	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/30/02	167	B	5.08	23.89	6.67	15.56	0	7.40	73	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
1/31/02	168	B	1.25	22.78	5.00	13.89	0	6.44	79	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/1/02	169	B	7.04	18.89	1.67	10.56	0	21.40	68	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/2/02	170	B	13.17	5.56	-3.89	1.11	0	10.30	51	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/3/02	171	B	17.00	5.00	-4.44	0.56	0	6.12	59	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/4/02	172	B	1.50	0.56	-8.89	-3.89	0.025	26.71	67	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/5/02	173	B	10.13	2.22	-10.56	-3.89	0	14.64	49	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/6/02	174	B	7.08	3.89	-2.78	0.56	1.016	3.54	64	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96
2/7/02	175	B	5.83	3.33	-0.56	1.67	0.229	5.31	91	54.12	13.52	32.24	60.91	65.39	90.59	8.33	43.26	80.29	51.96

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
1/9/02	146	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/10/02	147	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/11/02	148	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/12/02	149	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/13/02	150	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/14/02	151	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/15/02	152	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/16/02	153	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/17/02	154	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/18/02	155	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/19/02	156	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/20/02	157	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/21/02	158	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/22/02	159	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/23/02	160	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/24/02	161	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/25/02	162	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/26/02	163	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/27/02	164	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/28/02	165	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/29/02	166	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/30/02	167	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
1/31/02	168	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/1/02	169	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/2/02	170	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/3/02	171	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/4/02	172	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/5/02	173	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/6/02	174	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/7/02	175	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
2/8/02	176	B	8.63	12.78	-1.67	5.56	0	12.07	64	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/9/02	177	B	11.83	14.44	-6.67	3.89	0	7.08	68	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/10/02	178	B	10.42	8.89	2.22	5.56	0.279	8.69	83	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/13/02	181	B	8.00	6.67	-3.89	1.67	0	13.36	53	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/14/02	182	B	4.00	8.89	-9.44	0.00	0	2.25	62	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/15/02	183	B	9.92	11.11	-5.00	3.33	0	4.18	61	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/16/02	184	B	15.67	11.67	2.78	7.22	0.023	15.93	55	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/17/02	185	B	13.33	3.89	-3.33	0.56	0.254	21.24	67	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/18/02	186	B	10.00	10.00	-7.78	1.11	0	5.15	53	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/19/02	187	B	6.42	17.22	-8.33	4.44	0	4.83	45	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/20/02	188	B	7.67	12.22	5.56	8.89	0.025	12.39	66	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/21/02	189	B	11.17	13.33	1.67	7.78	0	17.38	68	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/22/02	190	B	4.92	5.56	-0.56	2.78	0	13.36	74	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/23/02	191	B	5.83	4.44	-6.67	-1.11	0	7.08	69	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/24/02	192	B	11.58	14.44	-9.44	2.78	0	3.06	60	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/25/02	193	B	3.92	18.33	-5.56	6.67	0	4.67	50	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/26/02	194	B	5.67	15.56	-2.78	6.67	0.023	15.93	58	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/27/02	195	B	7.17	-1.67	-9.44	-5.56	0.023	24.94	63	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
2/28/02	196	B	9.17	1.11	-10.56	-4.44	0.023	18.18	58	66.59	12.25	37.12	68.96	59.94	90.59	8.33	43.26	80.29	51.96
11/17/01	94	C	33.38	21.11	4.44	11.43	0	0.55	70	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/18/01	95	C	40.37	19.44	5.00	10.86	0	1.93	69	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/19/01	96	C	36.38	17.22	2.78	10.67	0	2.75	71	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/20/01	97	C	12.12	8.33	-1.67	5.83	0.001	3.42	70	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/21/01	98	C	12.60	12.22	-4.44	2.60	0	1.68	61	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/22/01	99	C	22.75	15.56	-2.78	5.14	0	1.04	59	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/23/01	100	C	11.95	17.78	-0.56	8.38	0.004	3.13	63	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/24/01	101	C	17.56	17.78	10.00	14.34	0.003	7.07	80	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/25/01	102	C	30.65	16.67	7.78	14.63	0	7.54	76	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/26/01	103	C	20.25	18.89	0.56	9.63	0.000	1.83	70	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/27/01	104	C	18.33	22.78	7.22	13.87	0	1.88	67	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
2/8/02	176	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/9/02	177	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/10/02	178	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/13/02	181	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/14/02	182	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/15/02	183	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/16/02	184	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/17/02	185	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/18/02	186	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/19/02	187	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/20/02	188	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/21/02	189	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/22/02	190	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/23/02	191	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/24/02	192	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/25/02	193	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/26/02	194	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/27/02	195	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
2/28/02	196	B	89.00	17.80	16.70	43.30	78.45	2.14	0.95	7.4	6	1.00	5.99	95	279	2.22	121	0.357	0	1
11/17/01	94	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/18/01	95	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/19/01	96	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/20/01	97	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/21/01	98	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/22/01	99	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/23/01	100	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/24/01	101	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/25/01	102	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/26/01	103	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/27/01	104	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
11/28/01	105	C	36.42	23.33	9.44	15.56	0.000	1.91	75	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/29/01	106	C	26.42	21.11	12.78	16.39	0	6.59	68	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
11/30/01	107	C	18.65	15.56	9.44	14.78	0.004	6.74	83	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
12/1/01	108	C	17.75	15.56	6.11	9.90	0.000	1.68	80	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
12/2/01	109	C	12.78	16.67	2.22	8.67	0	1.31	61	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
12/3/01	110	C	17.75	17.78	0.56	7.59	0	1.78	54	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
12/4/01	111	C	22.15	21.11	1.67	9.70	0	0.12	56	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
12/5/01	112	C	20.98	24.44	5.00	12.78	0	1.23	54	89.49	8.55	32.11	60.81	65.54	90.04	7.07	48.75	76.85	54.89
1/11/02	148	C	7.71	8.33	-1.67	5.18	0.008	4.12	77	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/12/02	149	C	14.48	7.78	-5.00	1.29	0.001	0.30	75	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/13/02	150	C	26.71	7.22	-2.22	1.60	0	4.53	62	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/14/02	151	C	16.69	10.56	-4.44	3.06	0	2.55	54	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/15/02	152	C	11.25	6.67	2.22	4.61	0	4.99	67	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/20/02	157	C	14.62	5.56	-2.78	0.71	0.004	2.58	75	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/21/02	158	C	14.46	9.44	0.00	4.08	0.005	3.96	71	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/22/02	159	C	14.54	12.78	-3.89	4.44	0	1.78	49	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/23/02	160	C	9.88	12.22	2.78	6.70	0.062	2.95	95	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/24/02	161	C	9.10	12.78	9.44	11.06	0.035	3.49	97	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/25/02	162	C	19.12	8.33	-2.22	3.52	0.001	2.62	67	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/26/02	163	C	12.81	13.33	-5.56	2.88	0	1.21	65	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/27/02	164	C	16.57	15.00	-3.33	4.64	0	1.04	72	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/28/02	165	C	18.40	16.11	-1.67	7.37	0	2.55	74	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/29/02	166	C	11.98	15.56	6.67	12.40	0	0.37	87	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
1/30/02	167	C	18.67	20.00	6.67	12.97	0.001	2.55	86	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/1/02	168	C	11.79	17.78	0.56	10.99	0.003	5.40	73	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/2/02	169	C	16.63	5.00	-2.22	0.72	0	2.95	57	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/3/02	170	C	12.10	3.33	-2.22	0.43	0	2.98	68	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/4/02	171	C	6.47	-0.56	-7.22	-2.61	0	6.37	72	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/5/02	172	C	10.71	1.11	-11.11	-4.99	0	1.98	52	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/6/02	173	C	9.23	4.44	-3.89	-0.62	0.018	1.64	73	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
11/28/01	105	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/29/01	106	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
11/30/01	107	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
12/1/01	108	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	0
12/2/01	109	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
12/3/01	110	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
12/4/01	111	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
12/5/01	112	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/11/02	148	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/12/02	149	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/13/02	150	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/14/02	151	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/15/02	152	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/20/02	157	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/21/02	158	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/22/02	159	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/23/02	160	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/24/02	161	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/25/02	162	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/26/02	163	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/27/02	164	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/28/02	165	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/29/02	166	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
1/30/02	167	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/1/02	168	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/2/02	169	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/3/02	170	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/4/02	171	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/5/02	172	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/6/02	173	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
2/7/02	174	C	10.67	4.44	0.56	2.06	0.015	1.58	94	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/8/02	175	C	10.83	10.00	-1.11	2.56	0	3.05	82	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/9/02	176	C	12.90	16.11	-4.44	5.71	0.001	4.39	59	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/10/02	177	C	13.44	17.22	5.00	10.02	0.001	5.80	66	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/11/02	178	C	10.38	2.22	-4.44	0.63	0.001	4.12	70	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/12/02	179	C	13.88	8.89	-7.22	1.09	0	3.92	61	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/13/02	180	C	9.00	7.78	-1.67	2.78	0	2.72	52	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/14/02	181	C	13.23	10.56	-5.56	1.68	0	1.81	54	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/15/02	182	C	6.86	11.67	-1.11	5.33	0	3.79	50	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/16/02	183	C	11.32	10.00	3.33	6.60	0.001	5.23	56	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/17/02	184	C	9.07	1.11	-2.22	0.41	0.001	4.09	67	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/18/02	185	C	10.37	11.67	-7.78	1.42	0	1.31	49	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/19/02	186	C	10.10	15.56	-2.78	6.99	0	1.74	35	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/20/02	187	C	11.42	13.89	7.78	11.41	0.005	10.23	61	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/21/02	188	C	10.13	12.78	3.33	8.56	0	4.59	62	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/22/02	189	C	10.25	3.33	-1.11	1.58	0	2.28	76	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/23/02	190	C	10.80	6.67	-2.22	0.79	0	1.41	68	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/24/02	191	C	12.46	15.56	-7.22	3.66	0	1.41	51	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/25/02	192	C	12.27	16.67	0.00	8.18	0	3.02	41	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
2/26/02	193	C	7.98	11.11	-2.22	4.83	0.001	5.40	64	51.91	13.30	33.42	61.50	64.07	90.04	7.07	48.75	76.85	54.89
11/21/01	98	D	8.65	11.11	-5.00	3.33	0	1.45	60	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/22/01	99	D	34.13	15.56	-5.56	5.00	0	2.09	56	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/24/01	101	D	25.63	12.22	7.22	10.00	0.330	9.33	97	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/25/01	102	D	13.54	19.44	3.89	11.67	0.660	9.66	84	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/26/01	103	D	4.60	19.44	1.11	10.56	0	0.48	75	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/27/01	104	D	14.47	22.78	3.89	13.33	0	2.41	79	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/28/01	105	D	4.29	22.78	6.11	14.44	0	4.02	75	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/29/01	106	D	5.85	17.78	8.33	13.33	0.023	8.53	80	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/1/01	108	D	5.09	18.33	2.78	10.56	0	6.28	72	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
2/7/02	174	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/8/02	175	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/9/02	176	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/10/02	177	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/11/02	178	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/12/02	179	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/13/02	180	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/14/02	181	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/15/02	182	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/16/02	183	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/17/02	184	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/18/02	185	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/19/02	186	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/20/02	187	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/21/02	188	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/22/02	189	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/23/02	190	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/24/02	191	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/25/02	192	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
2/26/02	193	C	47.24	14.38	23.18	36.95	69.25	0.31	0	0	26	3.81	6.82	8	52.4	2.00	16.2	0.046	38	1
11/21/01	98	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/22/01	99	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/24/01	101	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/25/01	102	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/26/01	103	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/27/01	104	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/28/01	105	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
11/29/01	106	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/1/01	108	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
12/1/01	108	D	5.09	18.33	2.78	10.56	0	6.28	72	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/2/01	109	D	4.10	15.56	-1.67	7.22	0	2.41	65	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/3/01	110	D	5.69	17.22	-5.56	6.11	0	0.00	64	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/4/01	111	D	23.15	21.11	-2.78	9.44	0	0.97	61	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/5/01	112	D	7.56	23.89	0.00	12.22	0	1.29	59	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/6/01	113	D	10.00	20.00	5.56	12.78	0	4.83	74	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/7/01	114	D	13.94	14.44	8.89	11.67	0.023	5.47	84	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/10/01	117	D	8.36	3.33	-2.22	0.56	3.378	4.51	88	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/11/01	118	D	2.81	8.89	2.22	5.56	0.279	4.35	96	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/12/01	119	D	2.72	7.22	5.56	6.67	0.025	9.82	96	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/13/01	120	D	9.23	14.44	6.11	10.56	0.229	2.41	94	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/14/01	121	D	5.06	13.89	8.89	13.89	0	11.75	78	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/15/01	122	D	7.39	9.44	0.00	5.00	0	11.59	78	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/16/01	123	D	5.25	10.00	-1.67	4.44	0	3.22	77	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/20/01	127	D	10.13	6.11	-3.33	1.67	0	22.53	55	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/21/01	128	D	4.74	5.56	-3.33	1.11	0	14.32	53	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
12/26/01	133	D	5.12	0.56	-7.78	-3.33	0	9.49	61	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/9/02	146	D	31.66	11.67	-2.78	4.44	0	16.74	57	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/10/02	147	D	20.28	14.44	4.44	9.44	0	14.48	73	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/11/02	148	D	4.35	11.11	-0.56	5.56	0.102	20.60	71	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/12/02	149	D	8.64	8.33	-6.11	1.11	0	7.40	69	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/13/02	150	D	7.38	6.11	-1.11	2.78	0.023	19.15	56	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/14/02	151	D	8.44	8.33	-7.78	0.56	0	6.44	67	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/15/02	152	D	30.25	7.78	-3.33	2.22	0	20.44	70	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/16/02	153	D	30.81	7.78	-3.89	2.22	0	6.76	55	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/19/02	156	D	12.94	0.56	-4.44	-1.67	1.829	7.08	79	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/20/02	157	D	11.88	3.33	-3.89	0.00	0.023	6.60	78	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/21/02	158	D	6.50	9.44	-2.78	3.33	0.076	11.59	73	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/22/02	159	D	9.81	11.67	-3.33	4.44	0	7.40	53	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/23/02	160	D	7.50	12.78	1.11	7.22	1.930	1.45	81	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
12/1/01	108	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/2/01	109	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/3/01	110	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/4/01	111	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/5/01	112	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/6/01	113	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/7/01	114	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/10/01	117	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/11/01	118	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/12/01	119	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/13/01	120	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/14/01	121	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/15/01	122	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/16/01	123	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/20/01	127	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/21/01	128	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
12/26/01	133	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	52	8.51	6.11	135	304	0.95	384	0.000	16	1
1/9/02	146	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	16	2.62	6.11	135	304	0.95	384	0.000	16	1
1/10/02	147	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	16	2.62	6.11	135	304	0.95	384	0.000	16	1
1/11/02	148	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	16	2.62	6.11	135	304	0.95	384	0.000	16	1
1/12/02	149	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	16	2.62	6.11	135	304	0.95	384	0.000	16	1
1/13/02	150	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/14/02	151	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/15/02	152	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/16/02	153	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/19/02	156	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/20/02	157	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/21/02	158	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/22/02	159	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/23/02	160	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1

Date	day	farm	mdc	maxtemp	mintemp	avgtemp	precip	wind	rh	fdm	fcp	fadf	fndf	ftdn	hdm	hcp	hadf	hndf	htdn
1/23/02	160	D	7.50	12.78	1.11	7.22	1.930	1.45	81	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/24/02	161	D	10.83	13.33	6.11	10.00	0.914	9.98	90	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/25/02	162	D	13.67	8.89	-5.00	2.22	0	9.82	65	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/26/02	163	D	8.67	14.44	-8.33	3.33	0	2.41	67	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/29/02	166	D	17.83	18.33	0.56	9.44	0	6.76	81	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/30/02	167	D	11.50	23.89	6.67	15.56	0	7.40	73	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
1/31/02	168	D	9.33	22.78	5.00	13.89	0	6.44	79	62.53	12.97	33.75	59.31	63.71	90.43	6.60	49.93	81.87	54.55
11/28/01	105	E	9.17	22.78	6.11	14.44	0	4.02	75	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
11/29/01	106	E	7.17	17.78	8.33	13.33	0.023	8.53	80	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
11/30/01	107	E	2.00	19.44	10.56	15.00	0.023	14.32	81	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/1/01	108	E	1.98	18.33	2.78	10.56	0	6.28	72	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/2/01	109	E	6.44	15.56	-1.67	7.22	0	2.41	65	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/3/01	110	E	5.38	17.22	-5.56	6.11	0	0.00	64	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/5/01	112	E	8.13	23.89	0	12.22	0	1.29	59	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/6/01	113	E	2.63	20.00	5.56	12.78	0	4.83	74	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/7/01	114	E	5.52	14.44	8.89	11.67	0.023	5.47	84	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/8/01	115	E	3.02	10.56	6.67	8.89	0.178	6.60	93	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/9/01	116	E	4.48	12.22	1.67	7.22	0	14.16	67	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/10/01	117	E	4.00	3.33	-2.22	0.56	3.378	4.51	88	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/13/01	120	E	6.85	14.44	6.11	10.56	0.229	2.41	94	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
12/14/01	121	E	2.04	13.89	8.89	13.89	0	11.75	78	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
1/9/02	146	E	4.43	11.67	-2.78	4.44	0	16.74	57	89.45	10.11	39.88	64.23	56.85	0	0	0	0	0
1/10/02	147	E	3.94	14.44	4.44	9.44	0	14.48	73	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/11/02	148	E	2.08	11.11	-0.56	5.56	0.102	20.60	71	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/12/02	149	E	1.51	8.33	-6.11	1.11	0	7.40	69	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/19/02	156	E	2.47	0.56	-4.44	-1.67	1.829	7.08	79	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/20/02	157	E	2.51	3.33	-3.89	0.00	0.023	6.60	78	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/21/02	158	E	1.83	9.44	-2.78	3.33	0.076	11.59	73	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/22/02	159	E	3.94	11.67	-3.33	4.44	0	7.40	53	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/29/02	166	E	3.08	18.33	0.56	9.44	0	6.76	81	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0
1/30/02	167	E	5.04	23.89	6.67	15.56	0	7.40	73	76.57	9.65	36.47	62.33	60.66	0	0	0	0	0

Date	day	farm	gdm	gcp	gadf	gndf	gtdn	ts	pass	plss	cn	sden	pa	dhw	dgw	ltw	sl	tspa	dcs	hay
1/23/02	160	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	8	1.31	6.11	135	304	0.95	384	0.000	16	1
1/24/02	161	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	3	0.49	6.11	135	304	0.95	384	0.000	16	1
1/25/02	162	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	3	0.49	6.11	135	304	0.95	384	0.000	16	1
1/26/02	163	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	3	0.49	6.11	135	304	0.95	384	0.000	16	1
1/29/02	166	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	3	0.49	6.11	135	304	0.95	384	0.000	16	1
1/30/02	167	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	3	0.49	6.11	135	304	0.95	384	0.000	16	1
1/31/02	168	D	39.23	16.21	27.65	41.85	67.10	0.001	0	0	3	0.49	6.11	135	304	0.95	384	0.000	16	1
11/28/01	105	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
11/29/01	106	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
11/30/01	107	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/1/01	108	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/2/01	109	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/3/01	110	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/5/01	112	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/6/01	113	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/7/01	114	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/8/01	115	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/9/01	116	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/10/01	117	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/13/01	120	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
12/14/01	121	E	0	0	0	0	0	2.11	34.3	50.3	52	5.35	9.72	0	0	2.22	670	0.218	0	0
1/9/02	146	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/10/02	147	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/11/02	148	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/12/02	149	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/19/02	156	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/20/02	157	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/21/02	158	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/22/02	159	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/29/02	166	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0
1/30/02	167	E	0	0	0	0	0	0.10	48	100	52	13.66	3.81	0	0	4.12	16	0.026	0	0

Appendix B

The SAS System
The REG Procedure
Dependent Variable: MDC
R-Square Selection Method

Number in Model	R-Square	C(p)	Variables in Model
1	0.2749	155.1108	DCS
1	0.1981	197.3678	PLSS
1	0.1593	218.6985	GTDN
1	0.1503	223.6711	GNDF
1	0.1487	224.5264	TSPA
2	0.3381	122.2836	SDEN TSPA
2	0.3378	122.4657	GDM DHW
2	0.3378	122.4657	GDM GTDN
2	0.3378	122.4657	GTDN DHW
2	0.3378	122.4657	GNDF DCS
3	0.4470	64.3376	GDM DHW HAY
3	0.4470	64.3376	GDM GTDN HAY
3	0.4470	64.3376	GNDF DCS HAY
3	0.4470	64.3376	GDM DCS HAY
3	0.4470	64.3376	DHW DCS HAY
4	0.5079	32.8244	SDEN LTW TSPA HAY
4	0.4813	47.4807	SDEN DHW TSPA HAY
4	0.4810	47.6553	GDM SDEN TSPA HAY
4	0.4796	48.4427	GNDF SDEN TSPA HAY
4	0.4794	48.5466	GTDN SDEN TSPA HAY
5	0.5351	19.8607	FDM SDEN LTW TSPA HAY
5	0.5190	28.7258	MINTEMP SDEN LTW TSPA HAY
5	0.5177	29.4500	RH SDEN LTW TSPA HAY
5	0.5164	30.1594	SDEN PA LTW TSPA HAY
5	0.5164	30.1601	PLSS SDEN LTW TSPA HAY
6	0.5491	14.1603	RH FDM SDEN LTW TSPA HAY
6	0.5447	16.5629	MINTEMP FDM SDEN LTW TSPA HAY
6	0.5414	18.4094	FDM FNDF SDEN LTW TSPA HAY
6	0.5413	18.4420	FDM FTDN SDEN LTW TSPA HAY
6	0.5396	19.3992	PRECIP FDM SDEN LTW TSPA HAY
7	0.5581	11.1961	MAXTEMP MINTEMP FDM SDEN LTW TSPA HAY
7	0.5575	11.5522	RH FDM FNDF SDEN LTW TSPA HAY
7	0.5568	11.9282	RH FDM FTDN SDEN LTW TSPA HAY
7	0.5545	13.1824	WIND RH FDM SDEN LTW TSPA HAY
7	0.5535	13.7408	MINTEMP FDM FTDN SDEN LTW TSPA HAY

Number in Model	R-Square	C(p)	Variables in Model
8	0.5675	8.0539	MAXTEMP MINTEMP FDM FTDN SDEN LTW TSPA HAY
8	0.5657	9.0050	MAXTEMP MINTEMP FDM FNDF SDEN LTW TSPA HAY
8	0.5633	10.3376	WIND RH FDM FNDF SDEN LTW TSPA HAY
8	0.5632	10.3885	RH FDM FTDN FNDF SDEN TSPA DCS HAY
8	0.5627	10.6623	RH FDM FTDN GDM SDEN PA SL HAY
9	0.5719	7.6016	MAXTEMP MINTEMP FDM FTDN FNDF SDEN TSPA DCS HAY
9	0.5712	8.0191	MAXTEMP MINTEMP FDM FTDN SDEN LTW SL DCS HAY
9	0.5712	8.0192	MAXTEMP MINTEMP FDM FTDN GDM SDEN PA SL HAY
9	0.5712	8.0203	MAXTEMP MINTEMP FDM FTDN PLSS SDEN DGW SL HAY
9	0.5712	8.0212	MAXTEMP MINTEMP FDM FTDN SDEN LTW SL TSPA HAY
10	0.5745	8.1776	MAXTEMP MINTEMP RH FDM FTDN FNDF SDEN TSPA DCS HAY
10	0.5738	8.5554	MAXTEMP MINTEMP PRECIP FDM FTDN FNDF SDEN TSPA DCS HAY
10	0.5738	8.5916	MAXTEMP MINTEMP RH FDM FTDN PLSS SDEN DGW SL HAY
10	0.5737	8.6057	MAXTEMP MINTEMP RH FDM FTDN GDM SDEN PA SL HAY
10	0.5737	8.6064	MAXTEMP MINTEMP RH FDM FTDN TS SDEN PA DHW HAY
11	0.5756	9.6034	MAXTEMP MINTEMP RH FDM FTDN FNDF TS PLSS SDEN LTW HAY
11	0.5756	9.6042	MAXTEMP MINTEMP RH FDM FTDN FNDF SDEN SL TSPA DCS HAY
11	0.5756	9.6047	MAXTEMP MINTEMP RH FDM FTDN FNDF SDEN LTW TSPA DCS HAY
11	0.5756	9.6069	MAXTEMP MINTEMP RH FDM FTDN FNDF SDEN LTW SL TSPA HAY
11	0.5756	9.6091	MAXTEMP MINTEMP RH FDM FTDN FNDF GDM TS PLSS SDEN HAY
12	0.5765	11.0883	MAXTEMP MINTEMP PRECIP RH FDM FTDN FNDF TS PLSS SDEN LTW HAY
12	0.5765	11.0892	MAXTEMP MINTEMP PRECIP RH FDM FTDN FNDF GDM TS PLSS SDEN HAY
12	0.5765	11.0918	MAXTEMP MINTEMP PRECIP RH FDM FTDN FNDF SDEN SL TSPA DCS HAY

Number in Model	R-Square	C(p)	Variables in Model
12	0.5765	11.0927	MAXTEMP MINTEMP PRECIP RH FDM FTDN FNDF SDEN LTW TSPA DCS HAY
12	0.5765	11.0963	MAXTEMP MINTEMP PRECIP RH FDM FTDN FNDF SDEN LTW SL TSPA HAY
13	0.5767	13.0000	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF TS PLSS SDEN LTW HAY
13	0.5767	13.0038	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF GDM TS PLSS SDEN HAY
13	0.5767	13.0044	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF SDEN SL TSPA DCS HAY
13	0.5767	13.0053	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF SDEN LTW TSPA DCS HAY
13	0.5766	13.0090	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF SDEN LTW SL TSPA HAY
14	0.5767	15.0000	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF PASS SDEN PA DHW TSPA HAY
14	0.5767	15.0000	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF PLSS SDEN DHW LTW TSPA HAY
14	0.5767	15.0000	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF SDEN PA DHW SL TSPA HAY
14	0.5767	15.0000	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF SDEN PA DHW DGW TSPA HAY
14	0.5767	15.0000	MAXTEMP MINTEMP PRECIP WIND RH FDM FTDN FNDF TS SDEN PA DHW TSPA HAY

NOTE: Models of not full rank are not included.

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Table 0-1: Results from the first evaluation procedure using Farm D.

Date	Observed MDC	Predicted MDC	maxtemp	mintemp	fdm	fndf	sden	ltw	tspa	hay
11/21/01	8.654	-20.240	11.11	-5.00	62.53	59.31	8.51	0.95	0	1
11/22/01	34.125	-19.439	15.56	-5.56	62.53	59.31	8.51	0.95	0	1
11/25/01	13.538	-20.617	19.44	3.89	62.53	59.31	8.51	0.95	0	1
11/26/01	4.596	-20.091	19.44	1.11	62.53	59.31	8.51	0.95	0	1
11/27/01	14.471	-20.095	22.78	3.89	62.53	59.31	8.51	0.95	0	1
11/28/01	4.288	-20.515	22.78	6.11	62.53	59.31	8.51	0.95	0	1
11/29/01	5.846	-21.718	17.78	8.33	62.53	59.31	8.51	0.95	0	1
12/1/01	5.087	-20.580	18.33	2.78	62.53	59.31	8.51	0.95	0	1
12/2/01	4.096	-20.174	15.56	-1.67	62.53	59.31	8.51	0.95	0	1
12/3/01	5.692	-19.178	17.22	-5.56	62.53	59.31	8.51	0.95	0	1
12/4/01	23.154	-19.094	21.11	-2.78	62.53	59.31	8.51	0.95	0	1
12/5/01	7.558	-19.185	23.89	0.00	62.53	59.31	8.51	0.95	0	1
12/6/01	10.000	-20.845	20.00	5.56	62.53	59.31	8.51	0.95	0	1
12/7/01	13.942	-22.346	14.44	8.89	62.53	59.31	8.51	0.95	0	1
12/10/01	8.356	-21.983	3.33	-2.22	62.53	59.31	8.51	0.95	0	1
12/11/01	2.808	-21.954	8.89	2.22	62.53	59.31	8.51	0.95	0	1
12/12/01	2.721	-22.846	7.22	5.56	62.53	59.31	8.51	0.95	0	1
12/13/01	9.231	-21.820	14.44	6.11	62.53	59.31	8.51	0.95	0	1
12/14/01	5.058	-22.433	13.89	8.89	62.53	59.31	8.51	0.95	0	1
12/15/01	7.394	-21.447	9.44	0.00	62.53	59.31	8.51	0.95	0	1
12/16/01	5.250	-21.044	10.00	-1.67	62.53	59.31	8.51	0.95	0	1
12/20/01	10.135	-21.338	6.11	-3.33	62.53	59.31	8.51	0.95	0	1
12/21/01	4.740	-21.425	5.56	-3.33	62.53	59.31	8.51	0.95	0	1
12/26/01	5.115	-21.367	0.56	-7.78	62.53	59.31	8.51	0.95	0	1
1/9/02	31.656	8.908	11.67	-2.78	62.53	59.31	2.62	0.95	0	1
1/10/02	20.281	7.977	14.44	4.44	62.53	59.31	2.62	0.95	0	1
1/11/02	4.346	8.401	11.11	-0.56	62.53	59.31	2.62	0.95	0	1
1/12/02	8.644	9.017	8.33	-6.11	62.53	59.31	2.62	0.95	0	1
1/13/02	7.375	14.274	6.11	-1.11	62.53	59.31	1.31	0.95	0	1
1/14/02	8.438	15.884	8.33	-7.78	62.53	59.31	1.31	0.95	0	1

1/15/02	30.250	14.956	7.78	-3.33	62.53	59.31	1.31	0.95	0	1

Table B-1 (continued): Results from the first evaluation procedure using Farm D.

Date	Observed MDC	Predicted MDC	maxtemp	mintemp	fdm	fndf	sden	ltw	tspa	hay
1/16/02	30.813	15.061	7.78	-3.89	62.53	59.31	1.31	0.95	0	1
1/19/02	12.938	14.035	0.56	-4.44	62.53	59.31	1.31	0.95	0	1
1/20/02	11.875	14.365	3.33	-3.89	62.53	59.31	1.31	0.95	0	1
1/21/02	6.500	15.112	9.44	-2.78	62.53	59.31	1.31	0.95	0	1
1/22/02	9.813	15.565	11.67	-3.33	62.53	59.31	1.31	0.95	0	1
1/23/02	7.500	14.898	12.78	1.11	62.53	59.31	1.31	0.95	0	1
1/24/02	10.833	18.134	13.33	6.11	62.53	59.31	0.49	0.95	0	1
1/25/02	13.667	19.540	8.89	-5.00	62.53	59.31	0.49	0.95	0	1
1/26/02	8.667	21.040	14.44	-8.33	62.53	59.31	0.49	0.95	0	1
1/29/02	17.833	19.968	18.33	0.56	62.53	59.31	0.49	0.95	0	1
1/30/02	11.500	19.681	23.89	6.67	62.53	59.31	0.49	0.95	0	1
1/31/02	9.333	19.823	22.78	5.00	62.53	59.31	0.49	0.95	0	1

Table B-2: Results from the second evaluation procedure using data from Farms A, B, C, and E.

	Farm	Observed MDC	Predicted MDC	maxtemp	mintemp	fdm	fndf	sden	ltw	tspa	hay
8/23/01	A	2.48	5.517	28.89	14.44	37.64	61.3	1.39	1.95	0.410	0
1/24/02	C	9.10	10.817	12.78	9.44	51.91	61.5	3.81	2	0.046	1
12/25/01	B	7.50	5.919	3.33	-8.89	89.18	68.12	2.17	2.22	0.357	1
9/24/01	A	0.00	4.618	17.78	10.00	37.64	61.3	1.39	1.95	0.410	0
12/26/01	B	8.04	5.274	0.56	-7.78	89.18	68.12	2.17	2.22	0.357	1
1/29/02	E	3.08	3.639	18.33	0.56	76.57	62.33	13.66	4.12	0.026	0
8/28/01	A	0.00	4.730	27.22	17.22	37.64	61.3	1.39	1.95	0.410	0
2/21/02	D	10.13	11.974	12.78	3.33	51.91	61.5	3.81	2	0.046	1
12/14/01	E	2.04	4.666	13.89	8.89	89.45	64.23	5.35	2.22	0.218	0
10/26/01	A	5.21	5.063	10.56	1.67	37.64	61.3	1.39	1.95	0.410	0
2/27/02	B	7.17	8.431	-1.67	-9.44	66.59	68.96	1.00	2.22	0.357	1
11/10/01	B	15.00	11.337	19.44	-5.00	37.32	60.32	2.17	2.22	0.357	0
2/6/02	C	9.23	12.035	4.44	-3.89	51.91	61.5	3.81	2	0.046	1
1/6/02	B	9.33	11.206	1.11	-7.78	89.18	68.12	1.00	2.22	0.357	1
1/10/02	B	12.17	10.029	14.44	4.44	54.12	60.91	1.00	2.22	0.357	1
9/12/01	A	5.81	6.151	25.56	8.33	37.64	61.3	1.39	1.95	0.410	0
1/20/02	C	14.62	11.999	5.56	-2.78	51.91	61.5	3.81	2	0.046	1
11/28/01	B	5.23	9.757	22.78	6.11	37.32	60.32	2.17	2.22	0.357	0
11/21/01	B	18.54	10.032	11.11	-5.00	37.32	60.32	2.17	2.22	0.357	0
1/28/02	C	18.40	13.442	16.11	-1.67	51.91	61.5	3.81	2	0.046	1
1/29/02	E	3.08	3.639	18.33	0.56	76.57	62.33	13.66	4.12	0.026	0
2/5/02	C	10.71	12.880	1.11	-11.11	51.91	61.5	3.81	2	0.046	1
12/14/01	E	2.04	4.666	13.89	8.89	89.45	64.23	5.35	2.22	0.218	0
11/22/01	C	22.75	23.825	15.56	-2.78	89.49	60.81	3.81	2	0.046	0
12/1/01	C	17.75	22.143	15.56	6.11	89.49	60.81	3.81	2	0.046	0
12/12/01	B	2.31	3.796	7.22	5.56	89.18	68.12	2.17	2.22	0.357	1
10/6/01	A	7.13	5.984	17.78	2.78	37.64	61.3	1.39	1.95	0.410	0
2/17/02	C	9.07	11.198	1.11	-2.22	51.91	61.5	3.81	2	0.046	1
2/3/02	B	17.00	10.231	5.00	-4.44	54.12	60.91	1.00	2.22	0.357	1
10/4/01	A	6.83	6.416	23.89	5.56	37.64	61.3	1.39	1.95	0.410	0

Table B-2 (continued): Results from the second evaluation procedure using data from Farms A, B, C, and E.

	Farm	Observed MDC	Predicted MDC	maxtemp	mintemp	fdm	fndf	sden	ltw	tspa	hay
11/3/01	A	4.46	6.122	20.00	3.89	37.64	61.3	1.39	1.95	0.410	0
8/16/01	A	4.92	4.922	27.78	16.67	37.64	61.3	1.39	1.95	0.410	0
12/6/01	E	2.63	6.253	20.00	5.56	89.45	64.23	5.35	2.22	0.218	0
1/29/02	C	11.98	11.778	15.56	6.67	51.91	61.5	3.81	2	0.046	1
9/13/01	A	9.80	6.307	27.22	8.89	37.64	61.3	1.39	1.95	0.410	0
8/19/01	A	5.31	4.625	27.22	17.78	37.64	61.3	1.39	1.95	0.410	0
12/26/01	B	8.04	5.274	0.56	-7.78	89.18	68.12	2.17	2.22	0.357	1
10/10/01	A	7.67	7.155	20.56	-1.11	37.64	61.3	1.39	1.95	0.410	0
1/8/02	B	11.08	10.304	2.78	-6.67	54.12	60.91	1.00	2.22	0.357	1
2/24/02	B	11.58	10.954	14.44	-9.44	66.59	68.96	1.00	2.22	0.357	1
12/19/01	B	4.23	6.471	12.22	-4.44	89.18	68.12	2.17	2.22	0.357	1
1/15/02	C	11.25	11.227	6.67	2.22	51.91	61.5	3.81	2	0.046	1
10/18/01	A	8.83	6.861	16.67	-2.78	37.64	61.3	1.39	1.95	0.410	0
11/18/01	C	40.37	22.962	19.44	5.00	89.49	60.81	3.81	2	0.046	0
12/7/01	E	5.52	4.753	14.44	8.89	89.45	64.23	5.35	2.22	0.218	0
1/22/02	C	14.54	13.340	12.78	-3.89	51.91	61.5	3.81	2	0.046	1
12/1/01	C	17.75	22.143	15.56	6.11	89.49	60.81	3.81	2	0.046	0
12/3/01	E	5.38	7.921	17.22	-5.56	89.45	64.23	5.35	2.22	0.218	0
11/26/01	C	20.25	23.716	18.89	0.56	89.49	60.81	3.81	2	0.046	0
1/13/02	C	26.71	12.155	7.22	-2.22	51.91	61.5	3.81	2	0.046	1

Vita

Amanda Lynn Masters, daughter of Stephen and Carol Masters, was born in Jacksonville, Florida on March 11, 1978. After graduating from Stafford Senior High School in Falmouth, Virginia in 1996, Amanda entered Virginia Polytechnic Institute and State University (Virginia Tech). She graduated in May 2000 after majoring in Biological Systems Engineering, with an emphasis in soil and water conservation engineering. Amanda started her graduate work in August 2000 in the Biological Systems Engineering Department at Virginia Tech. After finishing her Masters degree, Amanda will begin employment with the Freshwater Institute in Shepherdstown, West Virginia.