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Title: Implementing Best Management Practices in Small Commercial and Non-Commercial Animal Enterprises

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J. Ronald Miner

Small commercial and non-commercial animal enterprises (SCAEs) raise a few beef cows, horses, pigs, sheep, poultry, and other animals on a few acres. These enterprises are often located in suburban areas of watersheds and show potential for degrading water quality through to increased bacterial, nitrogen, and phosphorus concentrations. SCAEs implement Best Management Practices (BMPs) on a voluntary basis to control their water quality impacts.

Off-stream watering areas, with animal access to streams, and covered manure storages are two BMPs which were analyzed in this thesis for effectiveness in reducing bacteria, nitrogen, and phosphorus from entering surface and groundwater in four SCAEs. The four cooperating SCAEs were located in the Tualatin River Basin, and the potential water quality improvements from implementing these two practices in all SCAEs in the basin were discussed.

The BMP analyses use results from several studies. Two of these studies analyzed off-stream watering areas for reducing time animals spend watering at the stream. This time was measured and used to estimate the manure defecated in the stream. Reducing time animals spend at the stream decreases direct defecations in the stream and reduces

water quality impacts of SCAEs. A third study analyzed a pasture pump as a possible off-stream watering device. It was analyzed for its ability to provide water to 27 Holstein dairy heifers without limiting water consumption. Daily water consumption from the pasture pump was not significantly different than daily consumption from an open water trough. A fourth study predicted the rainfall required to produce runoff from pastured areas in the Dairy-McKay Hydrological Unit Area within the Tualatin River Basin. These required rainfall amounts and runoff frequency were predicted for summer and winter soil conditions.

The BMPs were analyzed for a variety of wet and dry conditions during the summer and winter. Off-stream watering areas were most effective in reducing water quality impacts of SCAEs for dry conditions during the summer and winter, while the covered manure storages were most effective during winter days of continuous rain. Off-stream watering areas reduced the time animals spent at the stream by 75%. Consequently, defecations at the stream were assumed to be reduced 75% and the SCAEs'water quality impacts decreased. Covered manure storages protect manure piles from rain and surface water runoff and prevent bacteria and nutrients from entering the stream or leaching to groundwater regardless of the weather. However, the amount prevented varies with weather conditions. An uncovered manure pile was estimated to cause no water quality impacts during dry weather. During wet weather, the bacteria and nutrients reaching the stream from an uncovered manure pile was estimated to be 60% of the quantity released. The maximum amount of nitrogen leaching to groundwater was estimated to be 10% of the amount applied to the pile since the previous rain.

In addition to implementation costs of BMPs, there are changes in annual revenue and costs associated with the management changes. Partial budget analyses were conducted for the four SCAEs to determine their changes in annual monetary returns to management. Both BMPs resulted in negative changes in annual returns to management for all four enterprises.

Implementing Best Management Practices in Small Commercial and Non-Commercial Animal Enterprises

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CHAPTER 1

INTRODUCTION AND OBJECTIVES

1.1 Introduction

All states have water quality standards for surface and groundwater sources. Sediments, bacteria, nitrogen, and phosphorus are common agricultural nonpoint source pollutants that degrade water quality. State agencies often regulate and support the implementation of Best Management Practices (BMPs) in a variety of agricultural operations to control their nonpoint source pollutants and maintain water quality standards.

Small commercial and non-commercial animal enterprises (SCAEs) raise a few beef cows, horses, pigs, sheep, poultry, and other animals on a few acres. They are sometimes referred to as non-confined animal feeding operations (non-CAFOs). SCAEs are often located in suburban areas of watersheds and show potential for degrading water quality through increased bacterial, nitrogen, and phosphorus concentrations. Presently in Oregon, state resource agencies educate and assist SCAEs in implementing BMPs and provide subsidies for certain implementation costs. SCAEs are unregulated and implement BMPs on a voluntary basis.

The Dairy-McKay Hydrological Unit Area (H.U.A.) is the largest sub-watershed in the Tualatin River Basin located outside of Portland, Oregon. The Tualatin River Basin is designated as water quality limited in terms of phosphorus and is the focus of many environmental cleanup programs. A majority of these programs has been implemented in the Dairy-McKay H.U.A. Some programs educate, assist, and subsidize SCAEs in implementing BMPs to reduce their water quality impacts.

These programs involving SCAEs introduce a variety of questions. How effective are BMPs in reducing bacteria, nitrogen, and phosphorus loads into surface and groundwater sources? Are these reductions the same for all weather conditions? If all SCAEs implement BMPs, what level of water quality improvement could be expected? What are the implementation costs of BMPs, and how do BMPs change annual monetary returns to management?

1.2 Objectives

This thesis has three main objectives consisting of:

1) Analyzing the effectiveness of two BMPs for reducing bacterial, nitrogen, and phosphorus loads in surface and groundwater from four SCAEs,
2) Discussing potential water quality improvements from implementing these two BMPs in all SCAEs in the Tualatin River Basin, and
3) Conducting economic analyses of these two BMPs for four SCAEs.

The two BMPs analyzed are off-stream watering areas and covered manure storages. Their effectiveness is analyzed for a variety of wet and dry conditions during the summer and winter. Four cooperating SCAEs are located in the Dairy-McKay H.U.A. in the Tualatin River Basin. The economic analyses review changes in annual monetary returns to management associated with the implemented BMPs.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review provides a basis to determine the water quality impacts of SCAEs and the potential reduction of these impacts by implementing Best Management Practices (BMPs). First, adverse effects of bacteria, nitrogen, and phosphorus on water quality, animal health, and human health are discussed. In addition, concentrations at which these adverse effects occur are stated. Second, livestock distribution in pastures and factors that affect this distribution are reviewed. Livestock distribution in pastures is necessary for estimating manure distribution and associated water quality impacts. Third, the quantity of manure defecated daily from a variety of animal types are given. This information is used to calculate quantities of bacteria defecated daily. Fourth, studies measuring and estimating bacterial quantities from livestock operations that enter surface and groundwater are reviewed. Bacterial die-off rates are an integral part of these studies. Fifth, quantities of nitrogen and phosphorus defecated daily from different animal types are given. Then, nitrogen and phosphorus nutrient pathways are discussed. Finally, studies measuring and estimating nitrogen and phosphorus movement in these pathways following different agricultural management practices are reviewed. Estimates of nitrogen and phosphorus entering surface and groundwater sources from agricultural management practices are included in the studies. A conclusion to the literature review is provided that summarizes information and assumptions that will be used to determine water quality impacts of SCAEs.

2.2 Monitoring Water Quality

Adverse Effects of Bacteria, Nitrogen, and Phosphorus

Livestock pose a threat to the health of other animals and humans. Their manure contains enteric and possible pathogenic microorganisms that may pass via water to animals and humans. Animal wastes from diseased or disease carrying livestock are capable of spreading a large number of bacteria-causing diseases, including salmonellosis and leptospirosis in other animals or humans (Moore et al., 1988a). Bacterial contamination of surface and groundwater by runoff and seepage from livestock operations is possible. Moore et al. (1988a) reviewed the literature and found few reported disease outbreaks implicating livestock as a cause, but stated that Jack and Hepper (1969) reported salmonellosis mortality was traced to seepage from a manure slurry tank overflow. Rankin and Taylor (1969) found several different species of bacterial pathogens in dairy manure slurry samples from various farms, and Miner et. al. (1967) showed beef feedlot runoff to contain a species of Salmonella.

Nitrogen, in the form of nitrate (NO_3), is water soluble and a threat to surface and groundwater quality. About 2000 cases of infant methemoglobinemia, a serious and potentially fatal health condition resulting from consuming water with elevated nitrites and nitrates, have been recorded worldwide during 1945-1972 (Shuval and Gruener, 1972). The safe minimum standard for nitrogen in drinking water is 10 mg/L and approximately 45 mg/L nitrate. Many pesticides are known to react with nitrite to form compounds known to be potent animal carcinogens (Murdock, 1988). Nitrogen has also been linked to algal blooms in the Chesapeake Bay causing low dissolved oxygen concentrations, decreased numbers of aquatic animals, and decreased survival of submerged vegetation (Fisher, 1989).

Phosphorus is a threat to water quality because it's often a limiting nutrient for algae. Aquatic systems evolve with low phosphorus levels as compared to terrestrial systems. Therefore, phosphorus lost from soils by erosion or leaching may be insignificant to the growth of terrestrial plants, but significant to the growth of aquatic plants (Gregory, 1993). Excess phosphorus in surface waters can cause an abundance of algal blooms that reduce dissolved oxygen and light penetration. These and other related effects to the aquatic system threaten the health of fish and other aquatic life in streams.

Monitoring Pathogenic Bacteria

Pathogenic bacteria are distributed in such small numbers that monitoring them is very complex and expensive, and identification methods have not been standardized. Therefore, indicator organisms are commonly used to monitor stream water quality. Characteristics of an ideal indicator organism include (Moore et al., 1982):

1) they should exist in large numbers in the contributing source and at levels far greater than pathogens associated with the waste,
2) the die-off or regrowth of the indicator organism in the environment should parallel that of the fecal pathogen, and
3) the indicator organism should only be found in association with the particular waste source making its presence a positive indication of contamination.

Indicator organisms must be easily quantified by testing methods applicable under a variety of samples and different sources. Methodology should be simple enough to be conducted on a routine basis in the laboratory. In addition, techniques must be reliable enough to essentially eliminate the possibility of false positive results from interfering flora.

Organisms that best fit these requirements are total coliform, fecal coliform, and fecal streptococcus. Moore et al. (1988a) stated that several studies show high levels of total coliform and fecal streptococcus contained in agricultural runoff regardless of the contamination of the land with animal fecal materials (Doran and Linn, 1979; Harms et al., 1975; Schepers and Doran, 1980; Kunkle, 1979). These same researchers found that fecal coliform was most sensitive to actual levels of fecal contamination of the soil when measured in runoff. Fecal coliform are only produced in the intestines of warm blooded animals which makes them more effective as a true sign of fecal contamination. Kunkle (1970), Harms et al. (1975), and the ORSANCO Water Users Committee (1971) all report that fecal coliform organisms are the most reliable indicator of fecal pollution of water.

The United States Environmental Protection Agency (USEPA, 1976) has developed limits on the concentration of bacterial indicator organisms in surface waters (Table 2.1). These bacterial water quality standards were developed for point sources. Jawson et al. (1982) proposed that these standards are not applicable to nonpoint source situations. Harms et. al. (1975) stated that total coliform counts of 1000 organisms/100 ml was never met for rainfall runoff from pastured areas, primarily due to the stable background levels of total coliform.

Table 2.1. Recommended bacteria levels for surface waters (USEPA, 1976), all counts are in number of organisms per 100 ml.

Beneficial Use	Total Coliform	Fecal Coliform
Public Water Supply		
minimal treatment	50	---
conventional treatment	10,000	2,000
Recreation		
limited contact	240	200
Irrigation	5,000	1,000

Assessing Bacterial Water Quality

If the concentration of indicator organisms in surface water is known, an assessment of the bacterial water quality and its health hazard can be estimated. From a human health standpoint, bacterial pathogens of the genus Salmonella may be of greatest interest. Prost and Riemann (1967) studied clinically healthy cattle and found approximately 13% infected with Salmonella. McFeters et al. (1974) found that Salmonella survive in water for lengths of time similar to those reported for fecal coliform. Geldreich (1970) studied the correlation between fecal coliform densities and Salmonella detection in fresh water (Table 2.2). There seems to be a high correlation and direct relationship between the presence of fecal coliform with density of greater than 201 per 100 ml and the presence of Salmonella. The source of the organisms was animal fecal contamination from warm blooded animals. The occurrence of Salmonella increased as the density of fecal coliform increased.

Table 2.2. Occurrences of Salmonella with fecal coliform organisms (Geldrich, 1970).

Fecal Coliform Density per 100 ml	Number of Examinations	Salmonella Occurrences Number	Percentage
1-200	29	8	27.6
201-2,000	27	19	85.2
over 2,000	54	53	98.1

2.3 Livestock Distribution in Pastures

Livestock grazing and confinement patterns are important in determining defecation placement. Once defecation placement has been determined, an analysis of how much of the manure's constituents enter surface and groundwater can be made. Biskie (1990) suggested three main factors determining cattle grazing patterns under range conditions: vegetation quality and quantity, location of watering area, and type of grazing system used. Even though these factors were for open range cattle and this study consists of various animals on confined pastures, some of these factors can still be used in understanding animal grazing patterns in SCAEs.

Vegetation Quality and Quantity

Vegetation quality and quantity is not likely to be a factor determining grazing patterns for SCAEs. Most SCAEs will have the same quality and quantity of vegetation in the pasture as in the riparian area due to irrigation and pasture management. If the pasture is not providing enough vegetation, the animals are then provided feed supplements. Also, the riparian areas are probably not large enough to sustain animals for a long period of time. If a difference exists between riparian and pasture vegetation conditions and animals have free access to the riparian area, the difference between the two areas will not last long. However, riparian areas providing shade and stream access might cause animals to linger during hot days. This is only speculation since studies on time animals spend in the riparian area have not separated the influence of watering areas from riparian shade.

Location of Watering Area

Past research has estimated the time cattle spend at their watering areas. Larsen et al. (1988) studied cattle in Central Oregon and found that 0.80% of their time was spent in the stream in August and 0.49% in November. The time spent in the stream seemed directly correlated with maximum and minimum air and water temperatures. More time was spent in the stream when air and water temperatures were higher.

Biskie (1990) reviewed Johnson et al. (1978), Dwyer (1961), Hull et al. (1960), Cully (1938), and Wagnon (1963) to determine the time animals spend at their watering area. Johnson et al. (1978) and Dwyer (1961) found that cattle spent less than 1% of the day drinking or resting in the stream. Hull et al. (1960) conducted a continuous 24 hour study of the time cattle spend drinking. The average time an animal spent drinking was 8.4 minutes (0.6% of their time) per day. Cully (1938) estimated an animal's average drinking time per day averaged 10 minutes (0.7% of their time).

Wagnon (1963) studied beef cows drinking from streams, water troughs, and puddles on a California range. The average time per cow spent drinking was two minutes per visit and three minutes per 24 hour observation period. If the water sources were shallow or muddy, the average time per visit increased to 5-6 minutes. The amount of time spent idling in the stream after drinking varied between visits. There were 48 drinking visits observed with 20 cows leaving the area immediately after drinking, 26 cows idled from less than one minute to four minutes, and 2 cows stood in or near the stream for 11 and 15 minutes.

Miner et al. (1992) evaluated the effectiveness of an off-stream watering area in reducing the time a group of hay-fed but free-ranging cattle spent in or immediately adjacent to the stream during the winter months. They theorized if the cattle spent less time in or immediately adjacent to the stream, then the manure defecated in this area would also be reduced.

The study was conducted over eight days, from late January to early February, using two different pastures. The control pasture had no water tank, and the animals used the stream for watering. The second pasture had a water tank, and the animals had a choice between watering at the creek or using the tank. The time cattle from the control pasture spent drinking or loafing at the stream per day averaged 25.6 minutes per cow over the eight days. For the same eight days, the time cattle from the second pasture spent drinking or loafing at the stream per day averaged 1.6 minutes per cow, while the time spent at the water tank per day averaged 11.6 minutes per cow. Comparing the times for the control and second pasture, the percent reduction is 94. Even when the feed source in the second pasture was placed equal distance between the water tank and the stream, the water tank was effective in reducing the time cattle spent in the stream.

This study also compared the time cattle spent at the creek within 4 hours of feeding for the control and second pasture. The time cattle spent at the control stream within four hours of feeding averaged 14.5 minutes per cow. The time cattle spent at the second pasture stream within four hours of feeding averaged 0.17 minutes per cow. Comparing these times for the control and second pasture, the percent reduction is 99.

Animal Grazing Systems

Two main types of cattle grazing systems have been used for estimating manure distribution patterns, continuous and rotational grazing. Continuous grazing systems allow cattle to roam over an area and cause the quantity of vegetation to differ within the area. Rotational grazing systems use fences and watering areas to manage cattle for a more uniform distribution and equal quantity of vegetation grazed in each area. Rotational grazing systems vary in intensity by the size of grazing areas and time interval of rotation. Walker et al. (1985) found short duration rotational grazing provides a more uniform distribution of manure over each area than continuous grazing. This is due to animals walking farther and having greater variability in their travel distance for the continuous grazing system. Since cattle tend to overgraze the high quality and quantity of riparian vegetation under continuous grazing systems, Platts (1981) suggests these systems are detrimental to riparian meadows.

Hafez (1969) concluded that fecal deposits from cattle were randomly distributed throughout a pasture. However, areas around fence lines, water troughs, gates, and bedding areas have shown an increase in manure concentration (Petersen et al., 1956).

2.4 Daily Manure Output

A summary of the manure production rates for common SCAE animal types is shown in Table 2.3 (MWPS Pub. No. 18, 1985). Biskie (1990) reviewed the literature to determine the number and weight of defecations from cattle. Wagnon (1963) found the daily number of defecations of grazing cattle varied by season due to changing forage quality and moisture. Daily defecations ranged from 11-18 with green forage in the beginning of the grazing season to eight defecations with dry forage at the end of the grazing season. No difference was found in number of daily defecations between cattle with diet supplements and those without.

Table 2.3. Manure production for common SCAE animal types. Values include defecated manure and urine (MWPS Pub. No. 18, 1985).

		Total Manure Production		
Animal	Size (lb)	lb/day	ft^3/day	gal/day
Beef Cattle	500	30	0.50	3.8
	750	45	0.75	5.6
	1000	60	1.00	7.5
	1250	75	1.20	9.4
Swine				
Nursery pig	35	2.3	0.038	0.27
Growing pig	65	4.2	0.070	0.48
Finishing pig	150	9.8	0.16	1.13
	200	13.0	0.22	1.5
Gestating sow	275	8.9	0.15	1.1
Sow and litter	375	33.0	0.54	4.0
Boar	350	11.0	0.19	1.4
Sheep	100	4.0	0.062	0.46
Poultry				
Layers	4	0.21	0.0035	0.027
Broilers	2	0.14	0.0024	0.018
Horse	1000	45	0.75	5.63

Free ranging cattle have been found to defecate an average of 12 times per day (Arnold and Dudzinski 1978; Julander 1955; Johnstone-Wallace and Kennedy 1944; Hafez

1969). Using manure production rates in Table 2.3 for an 1000 pound cow and assuming 12 defecations per day, each defecation would be 5 pounds (2.27 kg.) on a wet weight basis or 0.5% of the body weight.

Larsen et al. (1988) observed free ranging cattle in Central Oregon to estimate number of defecations in the stream during different seasons. The average time the cattle spent in the stream, per animal per day, was 11.19 minutes for summer, 2.65 for fall, 5.95 for winter, and 4.34 minutes for spring. The average number of defecations for free ranging cattle in the stream per day per animal was calculated to be 0.17 for the winter and spring, 0.19 for the fall, and 0.41 for the summer.

They also observed cattle in a feedlot during March with a stream close by for watering. The average time the cattle spent in the stream in March, per animal per day, was 3.9 minutes. The average number of defecations in the stream, per animal per day, was 0.38. They proposed that the number of defecations in the stream were higher for the feedlot cattle than free ranging cattle in March because the creek for the feedlot was closer. The animals were fed twice daily in the feedlot. After each feeding, the cows would go down to the stream together to drink. These cows also seemed to lounge in the stream for longer time periods than the free ranging cattle. This scenario would seem to resemble most SCAEs since the animals are on limited pasture and fed supplementary feeds in the winter.

2.5 Bacterial Organisms Entering Surface Water

The components necessary in estimating number of bacterial organisms entering a stream during a runoff event include: the number of organisms contained in the manure on the land, the number of organisms entering runoff, the number of organisms filtered out of the runoff by soil and vegetation, and volume of runoff.

Bacterial Organisms for Different Animal Types

The bacterial concentrations per gram of manure for different animal types is summarized in Table 2.4. Fecal concentrations vary widely between studies. Many factors cause this variability including animal age, feed ration, housing type, manure management system, and technique used for enumerating the bacteria. Factors directly influencing bacterial composition of manure are animal health, environmental stresses on the animal, and amount of cleaning and disinfecting in the livestock operation.

Table 2.4. Bacterial indicator concentrations in animal manure. All values are expressed on a wet basis.

Animal Type	Fecal Coliforms	Fecal Streptococci	Reference
Cow	---	1.3×10^6/g	Kenner et al.(1960)
Pig	---	8.4×10^7/g	"
Chicken	---	3.4×10^6/g	"
Cow	2.3×10^5/g	---	Geldreich et al. (1962)
Hog	3.3×10^6/g	---	"
Turkey	2.9×10^5/g	---	"
Chicken	1.3×10^6/g	---	"
Cattle	6×10^5/g	3.1×10^5/g	Maki and Picard (1965)
Horse	1.26×10^4/g	6.3×10^6/g	Geldreich (1978)
Swine	6.5×10^5/ml	3.4×10^6/ml	Crane et al. (1978)

The die-off rate of indicator organisms in soil is influenced by many variables. Crane and Moore (1984) reviewed the literature and stated the variables with greatest impacts seem to be temperature, pH, moisture, and nutrient supply. Lower temperatures tend to increase survival time, but elevated temperatures, especially when combined with dry conditions, increase die-off rates. Freezing and thawing have also been noted to reduce bacterial populations.

Chick (1908) developed a simple first order reaction that is used to estimate bacterial die-off rates. The reaction is commonly referred to as Chick's law and is:

$$\frac{Nt}{No} = 10^{-kt}$$

where: Nt = number of bacteria at time t

No = number of bacteria at time 0

t = time in days from time 0 to time t

k = die-off rate constants

Jones (1971) observed die-off rates of total coliforms and fecal coliforms in cattle fecal deposits. The die-off rates were derived using Chick's law and are listed in Table 2.5.

Table 2.5. Die-off rate constants for total coliform and fecal coliform organisms in cattle fecal deposits (Jones, 1971).

Organism	Die-off Rate, K ($days^{-1}$)
Manure Pile, Uncovered	
Total Coliform	0.022
Fecal Coliform	0.029
Manure Pile, Covered from Rain	
Total Coliform	0.007
Fecal Coliform	0.012

Moore et al. (1989) showed that there is a wide range of values in the literature for decay rates of bacteria in stored manure. They averaged the literature values to a constant die-off rate of 0.3. For waste applied to the field, they modified Reddy et al.'s (1981) equation that considers the influence of temperature, application method, and soil pH. For manure applied to the surface of a pasture, the modified equation is:

$$k = kl \times Ft \times Fap \times FpHk = kl \times Ft \times Fap \times FpH$$

where: k = die-off constant

kl = base die-off rate (0.50)

Ft = temperature correction factor ($1.0675^{(t-20 \text{ deg. Celsius})}$)

Fap = method of application (0.50 for surface)

FpH = soil pH factor

pH	Factor
3-6	1.69 - (0.26*pH)
6-7	0.25
7-8	(0.21 * pH) - 1.22

The release rate of fecal coliform from fecal deposits was determined by Thelin and Gifford (1983). They created uniform 203 mm diameter deposits using a pie pan and fresh cattle manure. These deposits were protected by a tarp and left outside for 3 to 30 days before the experiment began. The fecal coliform release rate was obtained by placing the deposits on an impervious platform and exposing them to simulated rainfalls of 5, 10, and 15 minute duration. The simulated rainfall rate was 61 mm per hour, making the 5, 10, and 15 minute duration equivalent to 5, 10, and 15 mm (0.20, 0.39, and 0.59 inches) of rainfall runoff. The runoff was collected in a drain pipe adjacent to the impervious plywood platform. The release rate equations derived from the experiment were:

5 minute duration: $\log(y) = 7.041 - 3.199 \log(x)$

10 minute duration: $\log(y) = 8.179 - 2.526 \log(x)$

15 minute duration: $\log(y) = 7.956 - 2.306 \log(x)$

10 and 15 minute duration combined:

$$\log(y) = 8.068 - 2.416 \log(x)$$

Where:

y is the average most probable number of fecal coliform released per 100 ml.

x is the number of days that the manure has not been rained on, where x is less than 2, set x = 2.

Since the fecal deposits were placed on an impervious platform, all of the rainfall became runoff. These release rates could be used for impervious areas, but if the manure was located in a vegetated pasture, some of the rainfall would infiltrate the soil. A similar study was conducted by Kress and Gifford (1984), but they placed the manure deposits on a very thin layer of sand. This sand covered a soil layer of unknown thickness which covered the same water collection platform. They used fecal deposits from 2 to 100 days old and obtained the equation:

$$\log(y) = 7.57 - 1.97 \log(x)$$

The data had a correlation coefficient of 0.923.

Several studies observed bacterial concentrations in streams after a runoff event. Doran and Linn (1979) collected rainfall runoff samples from a control area that was not grazed. They calculated that 95% of the samples exceeded the recommended standard of 200 fecal coliforms per 100 ml for primary contact recreation (USEPA, 1976). Robbins et al. (1972) calculated a yearly mean of fecal coliform concentrations to be 10,000/100 ml in runoff from watersheds that were not grazed in North Carolina. The 200 fecal coliform organisms per 100ml standard was also exceeded in many water samples from a watershed for more than one year after animals had been removed.

Schepers and Doran (1980) sampled runoff from three different pastures for differences in fecal coliform and fecal streptococcus counts. The pastures sampled included grazed pastures, pastures not grazed, and pastures that had never been grazed (control areas). The fecal coliform counts increased in the grazed pasture, but the fecal streptococcus counts remained unchanged.

Dixon et al. (1977) studied different cattle stocking rates and their impacts on bacterial concentrations in the runoff. The organism types and counts in the runoff for three stocking levels are shown in Table 2.6. Fecal coliform counts were the most sensitive to increased stocking levels. The total coliform counts increased with increasing stocking levels. In systems involving land areas and runoff, many coliform organisms of natural origin (non-enteric) can be introduced, making the total coliform test ineffective as a true sign of fecal contamination (Moore et al. 1982).

Table 2.6. Bacterial organisms in runoff water under different cattle stocking rates (Dixon et al., 1977).

	Stocking Rate		
Organism	40 Head / ha	10 Head / ha	0 Head / ha
Fecal Coliform	2.98×10^3	1.28×10^3	5.80×10^1
Fecal Streptococcus	2.57×10^4	1.60×10^4	1.45×10^3
Total Coliform	7.27×10^3	7.96×10^3	1.27×10^4

Land filters bacterial organisms during runoff. The filtration capacity of land is a function of slope and travel distance to the stream. Several studies have documented land's effectiveness in filtering bacterial organisms following manure application. Robbins et al. (1971) stated that 2 to 23% of fecal coliforms applied to fields or defecated daily by the animals were lost in runoff on an annual basis. However, these operations varied in management and losses are higher than those found in other studies (see review by Crane et al., 1983).

McCaskey et al. (1971) studied runoff water quality from dairy application sites where manure was applied in liquid, semi-liquid, or solid forms at annual application rates of 20 to 300 metric tons of dry matter per year. Crane et al. (1983) analyzed these results and calculated the maximum annual removal in runoff from these areas to be 0.06%, 0.007%, and 0.008% of applied total coliform, fecal coliform, and fecal streptococci respectively. These maximum rates of removal were from the solid manure application. The study was completed on minimal sloped sandy loam soil with bermuda grass cover.

Crane et al. (1978) applied liquid swine wastes to pasture plots and measured fecal coliforms and fecal streptococci in the runoff. If runoff occurred during the day of application, 58 to 98% of the fecal coliforms and 20 to 32% of the fecal streptococci applied in the manure were removed with the runoff. However, if runoff did not occur for three days, the percentage removal was dramatically reduced to 0.10 to 0.22% and 0.14 to 0.32% respectively. The decline was not due to die-off because bacterial counts in the surface soil revealed that a constant population of these bacteria were present during the 3 days. They hypothesized that increased residence time allowed greater contact between soil materials and applied microorganisms. This increased adsorption and fixation by ion exchange, surface charge attractive forces, and polymer bridging between solids and bacterial surfaces.

Crane et al. (1983) reviewed a subsurface drainage study by Korkman (1971) and found that total enterococci losses from an application of 50 tons/hectare wet weight of swine waste on a silty clay soil were 3%. The manure application was followed by a 100 mm irrigation. They considered this level of microbial loss to be a maximum because of the unusually high level of irrigation water applied and the small surface contact time between the swine waste and the soil.

Vegetated filter strips and buffer areas have been reviewed for their removal of bacterial organisms. Johnson and Moore (1978) found that vegetated filters are only effective in removing bacteria from overland flow to levels of 10^4 to 10^5 organisms per 100ml regardless of environmental conditions. Doyle et al. (1975) found a 99% reduction in fecal coliforms and fecal streptococci within 4 meters of a forested buffer strip, but the bacterial concentrations were still on the order of 10^4/100ml. Young et al. (1980) studied the effectiveness of vegetated buffer strips in controlling pollution from feedlot runoff. The maximum fecal coliform concentrations in the runoff leaving the filter were on the order of 10^5 to 10^6 / 100ml using a 27 meter long buffer.

Moore et al. (1989) developed an equation predicting the percent removal of bacteria from runoff by a buffer strip. This equation was based on Glenne's (1984) study of three Utah watersheds. Since Glenne's (1984) study found 55% bacterial removal from a 3 meter 1% sloped filter strip, Moore et al. (1989) used three meters as the minimal effective buffer width. The slope percentage of the buffer strip must be greater than 0 and no more than 15%. The maximum percent removal of bacteria is greater than 0 and less than 75%. The equation is as follows:

$$PR = 11.77 + 4.26 * S$$

where:

PR = Percent removal of bacteria

S = Buffer width (meters) $*$ 3.3/slope %

Larsen et al. (1993) studied the water quality benefits of manure deposited a short distance away from a stream rather than in a stream. Dairy manure was collected, mixed, made into uniform deposits of 1.2 kg., and stored. The manure deposits were placed on grass sod that overlay either sand or plastic (to simulate frozen soil) surfaces. The deposits were then irrigated with rainfall intensities of 5 and 10 cm/hr. Four distances, 0.0, 0.61, 1.37, and 2.13 meters, were chosen to determine the impact of distance on bacterial removal as a result of overland flow. Measurements were taken 10, 20, and 30 minutes after irrigation began. The zero distance was used to estimate the number of bacteria that could enter runoff from the fecal deposit. The total number of fecal coliforms in each manure deposit averaged 669 million and is the number of organisms that could have been directly defecated in the stream. This number of bacteria was reduced to 115 million (83%) at the edge of the manure pile (0 meters). If there were 1.35 meters or more between the collection points and manure pile, the fecal coliform reductions were 95% or greater.

No significant differences were found by Larsen et al. (1993) between both irrigation rates and bacteria concentrations, while a significant difference was noted in the number of fecal coliforms reaching the collection points between the two soil types. Approximately 2.2 million bacteria (0.3%) were delivered 2.13 meters away for the sand soil type (high infiltration) versus 13.7 million (2%) being delivered for the plastic soil type (simulated frozen ground). This illustrates that during those times of the year when infiltration rates are high, the hazard of elevated fecal coliform concentrations decrease.

This study also noted a decrease in number of bacteria released for the 0 meter buffer length when the irrigation rate increased. For the permeable and impermeable soil types and 5 cm/hour irrigation rate, the number of fecal coliforms entering runoff decreased 70% from 10 minutes to 30 minutes. Approximately 2.5 cm of runoff occurred by this time. For both soil types and 10 cm/hour irrigation rate, the number of fecal coliforms entering runoff decreased 80% from 10 to 30 minutes. Approximately 5.0 cm of runoff occurred by this time. This exemplifies the natural occurrence that as rain and runoff continue, runoff becomes channeled, more water runs around the manure pile rather than hitting hit, and the number of bacteria entering runoff decreases.

2.6 Bacterial Organisms Entering Groundwater

Bacterial removal in soil results from filtration, adsorption, and decay. The decay rate and its relationship between temperature, moisture effects, soil pH, and nutrients have already been discussed. Crane and Moore (1984) provided an extensive literature review of studies measuring bacterial organisms entering groundwater. They found surface soil to be of primary importance in reducing bacterial concentrations of infiltrating liquids. Adsorption of microorganisms onto clay particles and organic materials was shown to effectively remove bacteria from liquids. Weaver et al. (1978) showed 60-98% of the bacteria in a liquid effluent adsorbed on a soil composed of particles greater than 1 um in diameter using a differential centrifugation technique. They also found adsorption was related to clay content and bacterial species involved, probably due to differential electrical surface charges characteristic of each species.

Crane and Moore (1984) separated the main filtration mechanics in soil into three groups: (1) actual filtration by the soil matrix, (2) sedimentation of bacteria in the soil pores, and (3) bridging, where previously filtered bacteria reduce the pore diameters and increase the filtering action of the soil. Gerba et al. (1975) reported 92 to 97% of the bacteria applied in an effluent were removed in the first centimeter of soil and greater than 98% removal was accomplished in the first 5 cm of soil. McCoy (1969) found greater than 98% removal of bacteria from a waste effluent within the first 35 cm of soil. She noted that sand was less effective than clays in immobilizing the bacteria. Edmunds (1976) found total and fecal coliforms were effectively removed (greater than 95%) in the upper 5 cm of a gravelly glacial outwash soil from a heavy surface application of sewage sludge in a forest clearcut. It was hypothesized that the thin surface forest litter layer acted as a biological filter in deterring the movement of bacteria through the soil profile. Butler et al. (1954) obtained greater than 90% removal of the bacteria in the 0.5 cm surface organic mat.

Glotzbecker and Novello (1975) conducted a soil column study using sand and clay and showed that more than 99% of the applied bacteria were trapped in the soil, with clays giving the most efficient removal. A second column study by Weaver et al. (1978) using four soil types with various column depths, found an average reduction of 95% of the applied bacteria for a column depth of 5 cm and increasing to 99.5% with a column depth of 15 cm.

The rate and extent of bacterial movement in the soil depends heavily on the soil moisture and water flow regime. Crane and Moore (1984) summarized Griffen and Quail (1968), Wong and Griffin (1976) and Bitton et al.'s (1974) theory that at low soil water potentials, bacteria movement was restricted to the surface water films on soil particles, while at high soil water potentials the bacteria can move with the water in the soil macropores. Wong and Griffen (1976) also reported at low soil water potentials, the bacteria were more likely to be absorbed to charged particles in the soil because of their close proximity. Bitton et al. (1974) studied bacteria movement in both saturated and dry soil conditions and concluded that bacterial movement in soils at field capacity should be insignificant. Whereas movement under saturated flow conditions are increased due to zones of turbulent flow in the pores and dislodgment mechanisms.

2.7 Fate of Bacteria in Streams

In addition to surface runoff, bacterial organisms may reach the stream by direct deposit or by a rising water level washing organisms into the stream. Kunkle and Meiman (1967) conducted studies on mountain watersheds in Colorado. They observed that fecal coliform levels in the streams increase with increasing stream flows. Fecal coliform counts increased in the spring from a "flushing effect" of rising stream stages caused by snowmelt runoff. Kunkle and Meiman (1968) studied the same area and found an increase in total coliform, fecal coliform, and fecal streptococcus concentrations in the evening and early afternoon due to rising stream levels and a flushing effect. The highest fecal coliform concentrations occurred during peak runoffs in the spring, and all three bacterial groups had increased concentrations during summer storm flows.

Knowing the fate of organisms after entering the stream is necessary for estimating down stream effects. Biskie et al. (1988) studied the fate of bacterial organisms from a direct deposit of fresh cattle manure slurry into Bear Creek in Crook County, Oregon. The flow was estimated to be 2100 L/min. Approximately 95% of the fecal coliforms and fecal streptococci settled to the bottom sediments within 50 meters of the point of deposition. Bacterial counts returned to near background levels but remained noticeably higher, indicating the continuing resuspension of previously settled microorganisms.

The bacteria die-off and regrowth rates in streams and sediments are necessary to estimate the number of organisms that may be resuspended and travel downstream. The literature suggests survival of the organisms depends mostly on available nutrients and temperature (McFeters and Stuart, 1972). Davenport et al. (1976) illustrated an inverse relationship between bacterial survival and water temperature below 15^{o}C. The highest bacterial survival time occurred in 0^{o}C water under an ice cover. Mack (1974) found coliform bacteria to persist and multiply in natural waters with greater growth at 35^{o}C than at lower temperatures.

Scherer et al. (1992) studied first order die-off rates for fecal coliform and fecal streptococcus populations incubated for 30 days in 8°C water with and without stream sediments. A fine sediment (clay loam) and a coarse sediment (sandy loam) were collected from a watershed in Central Oregon for the experiment. When incubated in water and sediments, fecal coliform die-off rates ranged from 0.010 to 0.027 per day and ranged from 0.018 to 0.033 per day for fecal streptococcus. The bacteria die-off rates incubated in water and no sediments occurred in two stages. The first 15 days exhibited rates of 0.026 per day for fecal coliforms and 0.032 per day for fecal streptococci. During the next 15 days, the rates increased to 0.17 and 0.18 per day respectively. They suggested that for the first 15 days there was enough organic matter to support the populations. After this was exhausted, the measured die-off rates were similar to that typically measured for coliform in water, 90 percent in 3 to 5 days (Gerba and McLeod, 1976). Both the fecal coliform and fecal streptococcus concentrations reduced to one half in 2.8 days of incubation when no sediment was used. These fecal coliform and fecal streptococcus die-off rates in water support the observation that indicator bacteria survive for months (Scherer et al., 1988a). This is in contrast to more traditional measurements indicating more rapid die-off in water (Gerba and McLeod, 1976; Gary and Adams, 1985).

Biskie (1990) summarized first order die-off rates, calculated from Chick's Law for organisms attached to stream bottom sediments (Table 2.7) and organisms in aquatic environments (Table 2.8).

Another way bacterial organisms are released into stream flow is through animals, humans, or increased stream flows disturbing the sediments. Scherer et al. (1988a) studied effects of raking stream bottom sediments on release of bacterial organisms. On sites with no cattle in the area for at least sixty days, 13.8 million fecal coliforms and 228 million fecal streptococci were resuspended from one square meter of sediment. Just downstream from a feedlot containing 150 cattle, 330 million fecal coliforms and 5610 million fecal streptococci were resuspended. Later that year, the same site averaged 250 cattle in the feedlot and the number of bacteria resuspended were 760 million fecal coliforms and 1320 million fecal streptococci.

Table 2.7. Bacterial die-off rates in sediment (Biskie, 1990).

Organism Type	Sediment Type & Storage Temperature	Day 1-3 Die-off Rate k ($days^{-1}$)	Day 4-10 Die-off Rate, k ($days^{-1}$)	Day 11-40 Die-off Rate, k ($days^{-1}$)	Reference
TC	Mud, 20^0C	0.003	0.15	---	Van Donsel and Geldreich (1971)
FC	Mud, 20^0C	0.13	0.14	---	"
FS	Mud, 20^0C	0.06	0.06	---	"
Sa	Mud, 20^0C	0.14	0.14	---	"
FC	Sand, 5^0C	-0.333	0.154	0.035	Sherer et al. (1988b)
FC	Silt, 5^0C	-0.410	0.180	0.010	"
FC	Sand, 15^0C	-0.350	0.109	0.028	"
FC	Silt, 15^0C	-0.160	0.049	0.043	"
FS	Sand, 5^0C	-0.175	-0.009	0.035	"
FS	Silt, 5^0C	-0.197	0.092	0.028	"
FS	Sand, 15^0C	-0.159	0.054	0.025	"
FS	Silt, 15^0C	-0.124	0.113	0.049	"

* Organism abbreviations: TC = Total Coliform
FC = Fecal Coliform
FS = Fecal Streptococcus
Sa = Salmonella

Gary and Adams (1985) observed increases in bacterial organisms in a stream following the passage of a band of 1000 sheep. The samples were in stream moss beds and bottom sediments collected at one and two month intervals following the passage in mid-August. No sheep were near this site after the passage in mid-August. The results are given in Table 2.9.

Table 2.8. Bacterial die-off rates in aquatic environments (Biskie, 1990).

(Reference) & Aquatic System Description	Organism Type	pH	Water Temp. (^{0}C)	Length of Study	Die-off Rate (days^{-1})
(71) Well	Coliform	7.48	10 - 12	4 days	0.123
Water	Coliform	7.48			0.120
Inoculated with	Enterococci	7.48			0.096
Pure Cultures	Streptococci	7.48			0.108
(29) Storm	FC	---	20	14 days	0.630
Water Runoff	FC	---	10	14 days	0.107
(30) Storm	FC	---	20	14 days	0.099
Water Runoff	FC	---	10	14 days	0.282

* Organism abbreviation: FC = fecal coliform

Table 2.9. Bacterial counts in stream bottom sediment and moss. All counts are in units of fecal coliform per gram of wet weight.

Sample	August	September	October
Moss	2500	5.0	25
Sediment	570	0.3	4

McDonald et al. (1982) studied the impact of increased stream discharges on bacteria concentrations. An artificial increase in stream discharge was created by releasing water at different rates from a reservoir. Total coliform and Escherichia coli concentrations increased even as the discharge rate increased. Since there were no storm events during the study, the increased concentrations were due to release from bottom sediments and flushing of the stream banks.

Moore et al. (1988b) conducted a similar study in Central Oregon and observed increases in both fecal coliform and fecal streptococcus counts as the flow rate increased. They suggested that increased stream velocities disrupted the bottom sediments and released organisms into the stream flow (Table 2.10).

Table 2.10. Data from reservoir release study (Moore et al., 1988b)

Fecal Coliform (FC) Data

Stream Discharge (l / sec.)	Ratio of Increased Q to Base Flow	FC per 100 ml.	Average FC Released per sec.	Ratio of Increase In FC / sec. To Base Flow
30	0.0	200	6.00×10^4	0.00
75	1.5	500	3.75×10^5	5.25
150	4.0	3180	4.77×10^6	78.50

Fecal Streptococcus (FS) Data

Stream Discharge (l / sec.)	Ratio of Increased Q to Base Flow	FS per 100 ml.	Average FC Released per sec.	Ratio of Increase In FS / sec. To Base Flow
30	0.0	410	1.23×10^5	0.00
75	1.5	1028	7.71×10^5	5.27
150	4.0	7220	1.08×10^7	86.80

2.8 Manure as a Source of Nitrogen and Phosphorus

The total nitrogen and phosphorus in manure (feces and urine) varies by animal type and operation. For on-farm management, animal owners should test their own manure to determine available nutrients. Amount of nutrients produced per day from typical SCAE animal types are summarized by MWPS Pub. No. 18 (1985) in Table 2.11.

Nitrogen and Phosphorus Pathways

Estimating SCAEs nutrient impact on surface and groundwater involves evaluating possible nutrient pathways and their potential contribution to surface and groundwater. Nitrogen pathways include volatilization, denitrification, runoff, deep leaching, plant uptake, and net accumulation in the soil system. The forms of nitrogen that exist in manure upon defecation are organic nitrogen, ammonium (NH_4^+), and urea. Moore and Gamroth (1989) suggested approximately 50% of the nitrogen in fresh manure is in the organic form and appears as partially digested feed and microorganisms. The other 50% is inorganic, usually as ammonium, and subject to significant losses during collection, storage, and application.

Table 2.11. Amount of nutrients produced per day per animal type (MWPS Pub. No. 18, 1985).

Animal	Size (lb)	N lb/day	P lb/day	P2O5 lb/day
Beef Cattle	500	0.17	0.056	0.127
	750	0.26	0.084	0.191
	1000	0.34	0.11	0.250
	1250	0.43	0.14	0.318
Swine				
Nursery pig	35	0.016	0.0052	0.0118
Growing pig	65	0.029	0.0098	0.0223
Finishing pig	150	0.068	0.022	0.050
Finishing pig	200	0.090	0.030	0.068
Gestating sow	275	0.062	0.021	0.048
Sow and litter	375	0.230	0.076	0.173
Boar	350	0.078	0.026	0.059
Sheep	100	0.045	0.0066	0.015
Poultry				
Layers	4	0.0029	0.0011	0.0025
Broilers	2	0.0024	0.00054	0.00123
Horse	1000	0.27	0.046	0.105

Following defecation, these forms can undergo nitrification and ammonification to produce nitrate (NO_3^-) and ammonia (NH_3) respectively. Ammonia is subject to loss as a gas through volatilization. Nitrate is soluble in water and is available to plant roots, may accumulate in soil water, or may leave the site with surface or groundwater. Nitrate may also be converted to nitrogen gas (N_2, N_2O) by denitrification under anaerobic conditions. Both ammonium and organic nitrogen can accumulate in the soil, and ammonium can absorb onto clay particles by cation exchange. Nitrogen also occurs naturally in plant material and rain water.

Phosphorus is present as ortho-phosphate (P_2O_5) and organic phosphorus upon defecation. In contrast to nitrogen, phosphorus does not have a gaseous phase in its biogeochemical cycle. Phosphorus travels as an inorganic compound, organic compound, or as an ion. The ion is soluble in water and is available for plant uptake, accumulation in soil water, or movement off site in surface and groundwater. The phosphorus ion also adheres readily to soil particles, by adsorption and absorption, forming inorganic compounds. Inorganic and organic compounds can be soluble or insoluble and may accumulate in the soil or carried off site by erosion.

Once phosphorus reaches the stream, the compounds may transform to bioavailable forms through enzymatic processes of algae or chemical hydrolysis reactions. Phosphorus occurs naturally as compounds in rocks that form the earth's crust, and in overlying soil layers. Phosphorus does not occur in precipitation, but may travel with wind blown particles.

Nitrogen and Phosphorus Losses with Management

Waste handling systems affect nutrient losses to soil from manure and bedding and the amount of nitrogen lost through volatilization. The MWPS Pub. No. 18 (1985) suggests 40 to 60% of defecated nitrogen is lost when collected and piled under open lot conditions, and 20 to 40 % is lost using enclosed area storage, mostly as ammonia gas. Other nitrogen loss pathways under open lot conditions include runoff, leaching, and soil absorption. Nitrogen loss as ammonia from land is greater during dry, warm conditions (spring and summer months). Phosphorus losses are negligible during collection and storage except for open lots or lagoons where 20 - 40% can be lost.

Moore and Gamroth (1989) summarized nutrient retention values of manure from various animal types as they relate to storage systems, application methods, and use of manure as a fertilizer to crops (Table 2.12).

Table 2.12. Percentage of original nutrient content of manure retained by various storage systems (Moore and Gamroth, 1989).

	Beef		Horse		Poultry		Sheep		Swine	
Method	N	P	N	P	N	P	N	P	N	P
Dry (w/ roof)	---	---	70	90	60	90	65	90	---	---
Open Lot	60	70	60	70	---	---	55	70	60	70

Martins and Dewes (1992) analyzed the nitrogen losses from composted cattle, swine, poultry, and mixed manure over a period of 98 to 114 days. The greatest nitrogen losses are caused by gaseous admissions of ammonia and nitrogen and ranged from 46.8% for cattle manure to 77.4% for poultry manure of initial nitrogen. Additional nitrogen loss was due to leaching of ammonium and nitrate and ranged between 9.6% for the mixed manure and 19.6% for the poultry manure. Most of the leaching (>70%) occurred within the first ten days before the start of irrigation.

The MWPS Pub. No. 18 (1985) suggested 15 to 30% of nitrogen is lost during broadcast application of solid manure within four days. Most of these losses occur in the first 24 hours after application. They suggest that losses can increase to 25 to 50% of total nitrogen from decomposition and leaching when applied in late fall or winter.

Moore and Gamroth (1989) stated that 80% of nitrogen and 100% of phosphorus applied to cropland by broadcast of solids, is available for plant uptake. This includes application and preutilization losses (Table 2.13).

Table 2.13. Percentage of field-applied manure nitrogen available to plants after denitrification losses, by region (Moore and Gamroth, 1989).

Location	%N available
Coast	80
Willamette Valley and Southern Oregon	
Irrigated	87
Nonirrigated	92
Eastern Oregon	95

Once the manure is applied to the pasture, the organic portion can undergo mineralization and become available for plant uptake. The MWPS Pub. No. 18 (1985) summarized the percent of organic nitrogen that undergoes mineralization during the first cropping season after application (Table 2.14). Organic nitrogen released during the second, third, and fourth cropping years after initial application is about 50%, 25%, and 12.5%, respectively, of that mineralized during the first cropping season (Table 2.14). Nearly all of the phosphorus in animal wastes are available for plant use the year of application. After a few years of application, the amounts of organic nitrogen available are equal to the amount applied.

Table 2.14. Amount of organic nitrogen mineralized (released to crops) during first cropping season after application of animal manure (MWPS Pub. No. 18, 1985).

Manure Type	Manure Handling	Mineralization Factor
Swine	Fresh	0.50
	Anaerobic liquid	0.35
	Aerobic liquid	0.30
Beef	Solid without bedding	0.35
	Solid with bedding	0.25
Sheep	Solid	0.25
Poultry	Solid with litter	0.30
	Solid without litter	0.35
Horses	Solid with bedding	0.20

Moore and Gamroth (1989) suggested nutrient application rates that do not greatly exceed the total amount of nutrient uptake in pastures for regions in Oregon (Table 2.15). These values not only differ by region, but also by operations that harvest or graze, irrigate or not irrigate their pasture. Harvesting by cutting of hay (green chopping) is the most efficient harvest and removes all of the grass. The amount of applied fertilizer should be reflected in the nutrients that are removed from the field. Because moisture availability is critical to grass production, the irrigated and nonirrigated choices reflect these levels of production. They also noted that manure nutrients, especially nitrogen, are used more efficiently by grasses and cereals than by legumes.

Table 2.15. Suggested nutrient application rates (lb/acre) for pastures, by location in Oregon, harvested and grazed (Moore and Gamroth, 1989).

	Harvested		Grazed	
Location	N	P	N	P
Coast	220	28	165	24
NW valleys				
Irrigated	200	25	150	22
Nonirrigated	110	21	80	20
So. Oregon				
Irrigated	180	24	75	20
Nonirrigated	80	20	50	19
E. Oregon	200	25	120	21

Kelly et al. (1993) measured nitrogen movement into its pathways following manure application to ryegrass-orchard grass pasture on three sites. Fresh manure was applied to supply either 0, 168, 336 and 504 kg/ha (0, 150, 300, and 450 lb/ac) of nitrogen each year. Pathways evaluated included volatilization, denitrification, runoff, deep leaching, plant uptake, and net accumulation to the soil system. Sites included a Quillamook silt loam soil in Tillamook County that receives 2.34 m (92 in) of rainfall per year, and two sites located on a Waldo silty clay loam and an Amity silt loam in the mid-Willamette Valley which receive 1m (40 in) of rainfall per year. Manure was applied six to seven times, with most of the application occurring in the spring and summer. The study was conducted over two years and showed high variability in nitrogen values for both years. The sites had not reached an equilibrium after two years.

The crop yields of dry matter and nitrogen increased up to the 300 lb/acre-year application rate, but dropped off under 450 lb/acre-year rate. Volatilization rates increased with application rate and ranged from 14 to 20% of nitrogen applied annually. Denitrification rate is a function of application amount and soil moisture and can be up to

50 lb N/ac-yr at 450 lb N/ac-yr application. Nitrogen concentrations in runoff was the most variable, and no statistical difference between application rates were observed. Both average ammonia and nitrate concentrations were generally less than 9.0 mg/l as nitrogen.

All sites showed the highest nitrogen levels in spring runoff. Nitrogen loss was estimated to range between 4 to 14 lb N/ac-year. Deep leaching losses were also highly variable and significant differences between application rates were not found. Losses ranged between 5 and 18 lb N/acre-year.

Hall and Risser (1993) studied the effects of agricultural nutrient management on nitrogen fate and transport for a 47.5 acre site in Lancaster County, Pennsylvania. The annual rainfall average is 43.5 inches, and the soils were silt loams and silt-clay loams. Manure and commercial fertilizers were initially applied at 480 lb nitrogen per acre-year to crops of corn (summer), tobacco (5 acres), and vegetables and grasses (winter time). Harvest, surface water runoff, volatilization, and groundwater outflow averaged 37, less than 1, 25, and 38 percent of nitrogen loss from the site. Denitrification was assumed to be negligible. Manure and commercial fertilizers were later applied at 320 pounds per acre-year. Nitrogen loads in groundwater decreased by 30 percent (26% of applied) following the change, while the other losses stayed relatively constant.

Estimating the amount of phosphorus lost is difficult. Since phosphorus occurs naturally, it is difficult to estimate the amount from manure as opposed to existing sources. Therefore, the literature is highly variable in estimating the amount of phosphorus from animal operations that contribute to surface and groundwater.

The capacity of soils to adsorb phosphorus varies widely and is one reason for this variance in the literature. For phosphorus-enriched surface water to recharge groundwater aquifers, it must first percolate through the overlying layers of soil and other materials. McAllister and Logan (1978) observed the variability of absorption capacities in soils of the Maumee River Basin, Ohio. They studied the phosphorus content, availability, and adsorption capacity for soils and bottom sediments. The soils yielded total phosphorus amounts ranging from 450 to 1018 ug/g, available phosphorus amounts ranging from 2.7 to 46.4 ug/g, and adsorption maximums ranging from 199 to 287 ug/g. In contrast, the bottom sediments yielded total phosphorus amounts ranging from 476 to 1260 ug/g, available phosphorus amounts ranging from 19.0 to 36.7 ug/g, and adsorption maximums ranging from 222 to 4870 ug/g.

The concentration of phosphorus in groundwater is determined by the phosphorus adsorption characteristics of the overlying soil layers. Kao and Blanchar (1973) found the soils with high adsorption capacities tend to become enriched over time as phosphorus becomes available to the soil particles by fertilizers, organic materials, or weathering. They observed an Indiana soil that doubled the phosphorus content after 82 years of fertilization, while leaving the adsorption capacity nearly unchanged. Generally, the concentrations of phosphorus in groundwater are low, due to the high adsorption capacities of most soils, although extremely porous or cracked soils may not allow sufficient time for complete adsorption to take place (Nelson and Logan, 1983; Keup, 1968).

Nelson and Logan (1983) stated that the chemical forms phosphorus undergoes during transport vary widely and rapidly, its transport may be better understood by considering the two physical forms of transport, particulate and soluble. Particulate phosphorus forms include adsorbed, both as labile or exchangeable on the soil matrix and organic material, organic forms such as phospholipids and phytus, and precipitates that are already present in the soil or reaction products with Ca, Fe, Al, and other cations (Nelson and Logan, 1983). Soluble phosphorus can be directly contributed to soil, surface water, and groundwater by deposit of animal wastes and fertilizers, or indirectly by phosphorus equilibrium reactions during rainfall and runoff events. The soluble (dissolved) forms include orthophosphates, inorganic polyphosphates, and organic phosphorus compounds. An equilibrium reaction occurs when water runs over the soil or leaves of plants and causes desorption of phosphorus from the thin surface layer it is in contact with (Sharpley, 1981; Sharpley et al., 1981; Sharpley and Menzel, 1987).

Wolf (1993) summarized the literature by stating the largest amounts of phosphorus carried in runoff are from phosphorus adsorbed to sediments undergoing erosional processes and not from leachates. Fine-textured soils, such as clays and silts, have the greatest affinity for phosphorus (Day et al., 1987; McAllister and Logan, 1978; Nelson and Logan, 1983; Sharpley and Menzel, 1987). Soil erosion processes from overland flow are selective, with fine-textured soils being more likely to be carried in runoff. It has been suggested that any management practices that reduce surface runoff and erosion will effectively reduce phosphorus loading to surface waters.

Vegetated filter strips and buffers have been used to reduce the amount of nutrients and sediment entering streams. Cooper et al. (1987) suggested the phosphorus content of riparian soil increases from the outer edge of the riparian zone (next to the upland areas) to the inner edge next to the stream. This was due to the clay with adsorbed phosphorus having a slower settling rate compared to the coarser fraction of the soil. Therefore, the phosphorus travels a longer distance into the buffer strip before being trapped.

Brinson et al. (1981) explained that the phosphorus being trapped in the riparian zone is being transformed and stored into different components of the riparian ecosystem. A change in the biomass of any of these components will cause a change in the phosphorus storage values. These components include soil, above and below ground wood, canopy leaves, litter layer, and ponded layer of water on the surface. These components, especially the leaves, may cause seasonal fluxes and influence phosphorus cycling.

The capacity of the riparian zone to hold nitrogen without release into the surface water is also related to nutrient cycling. Peterjohn and Corell (1984) showed the dominant pathway of nitrogen transport from agricultural fields is through subsurface flow and reaches the stream as ammonium and nitrates. The effectiveness of a riparian zone in controlling nitrogen runoff is mainly related to its capacity for nitrate uptake and how much is lost through denitrification and volatilization. Brinson et al. (1981) suggested 10 to 55 kg/hectare/year of nitrate nitrogen was denitrified in riparian foliage along North Carolina streams.

The effectiveness of vegetated buffer strips in reducing nutrient loading to streams will depend on various factors and vary widely. Pennsylvania State University (1992) provided estimates of relative gross effectiveness of sediment control measures as reported in the literature. Vegetated filter strips as a control measure had relative gross effectiveness values of 75%, 70%, and 65% for total phosphorus, total nitrogen, and sediment, respectively. Relative gross effectiveness means they are estimates and would vary widely depending on site-specific variables such as soil type, crop rotation, topography, tillage, and harvesting methods. Extreme spatial and temporal variations are common even within small watersheds.

The EPA (1993) has determined that vegetated filter strips improve water quality and can be an effective management practice for controlling nonpoint pollution from silvicultural, urban, construction, and agricultural sources of sediment, phosphorus, and pathogenic bacteria. They summarized a few vegetated filter strip effectiveness studies as shown in Table 2.16.

Peterjohn and Corell (1984) studied the role of a riparian forest in absorbing and conserving the nutrients from cropland runoff. The experiment was conducted on a Maryland agricultural watershed with approximately 50m wide riparian zone. Measurements were taken of phosphorus and nitrogen concentrations at 0m, 19m, and at the streams edge (50m) for different seasons of the year. Total nitrogen inputs to the riparian forest consisted of 17% in precipitation, 61% in groundwater, and 22% in surface runoff. Phosphorus inputs included 3.5% in precipitation, 94% in surface runoff, and 2.5% in groundwater flow. These measured inputs suggested that most of the nitrogen entered the riparian zone in the dissolved form and most of the phosphorus entered in the particulate form.

Table 2.16. Effectiveness of vegetated filter strips (VFS) for sediment, nitrogen (N), phosphorus (P) and total coliform removal (EPA, 1993).

Study and Reference	VFS Length (meter)	Vegetation	Sediment Removal (%)	Total N Removal (%)	Total P Removal (%)	Total Coliform Removal (%)
(17) Simulated feedlot runoff	4.6	orchard grass	79	64	58	---
" "	9.1	"	90	74	68	---
(18) Simulated cropland runoff	4.6	orchard grass	63	50	57	---
" "	9.1	"	78	67	74	---
(63) Simulated cropland runoff	4.6	orchard grass	72	17	41	---
" "	9.1	"	86	72	53	---
(113) Simulated feedlot runoff	35-41	corn	86	92	91	70
" "	"	orchard. grass	66	87	88	53
" "	"	sorghum	82	84	81	81
" "	"	oats	75	73	70	70
" "	"	average	79	84	83	---

Surface runoff concentrations generally decreased with increase in length of riparian zone for total suspended particulate, particulate phosphorus, dissolved phosphorus, orthophosphate, nitrate, ammonium, and organic nitrogen for all seasons (Peterjohn and Corell, 1984). However, the degree of reduction down the riparian zone varied from season to season. Groundwater concentrations of nitrate generally decreased with distance through the riparian zone, but ammonium and phosphorus concentrations increased. They suggested that decomposing litterfall and mineralization of microbial mass attributed to release of ammonium ions, while increased dissolved fractions of phosphorus may have caused increased phosphorus concentrations. The retention capacity of the riparian forest was estimated to be 89% of inputs with most (75%) of the losses through groundwater. The retention capacity of the riparian forest was estimated to be 80% for phosphorus with 59 and 41% of the losses through surface runoff and groundwater flow respectively. Since most of these changes occurred in the first 19 meters of riparian zone, they concluded this was the most effective area in trapping nutrients.

2.9 Conclusion

There is limited literature available pertaining to analysis of on-farm installations of Best Management Practices to reduce livestock impact on water quality. The following paragraphs summarize the material mentioned in this review that will be used for analyzing SCAEs. Several assumptions will be made to relate past studies and their results to small enterprise situations.

Animal Distribution

To predict the amount of nutrients and bacteria entering surface water runoff, groundwater, or streams while animals are grazing pastured areas, the animals' distribution and associated location of defecations must be determined. Animals and manure deposits are assumed to be randomly and evenly distributed in pastured areas with the exception of watering areas, fences, gates, and shaded areas. This will not be assumed when the animals do not have adequate pasture to graze and are fed supplementary feeds.

Implementing off-stream watering areas and devices are assumed to only change the animals' distribution from the stream to the off-stream watering areas. Separate studies will be conducted to estimate the time animals spend at the creek with and without an off-stream watering area during the summer. These results are assumed to be the same for all weather conditions. Past literature suggests that open range animals spend less time at the stream during the winter than summer. This is probably due to increased moisture in the pasture being grazed and the air temperature. In contrast, SCAEs must supplementary feed their animals during the winter when grazing is minimal to none. Therefore, animals in SCAEs will probably not get extra moisture from their food source and will spend the same time at the stream regardless of season.

Bacteria and Nutrients in Manure

The MWPS Pub. No. 18 (1985) will be used to estimate an animal's daily production of manure nitrogen, and phosphorus (Tables 2.3 and 2.12). Daily number of defecations for both cows and horses are assumed to be twelve. The number of indicator bacterial organisms in manure will be estimated from the values given in Table 2.5.

Bacterial die-off rates in individual manure piles will be estimated using Moore et al.'s (1989) equation for manure applied to the surface of a pasture. For large manure piles, the die-off rate will not be a factor of the number of bacteria released and will not be calculated.

Bacteria and Nutrient Release Rates

Bacteria die-off rates and nutrient losses are different for separate manure piles than one larger manure pile. For individual defecations in off-stream watering areas, bacteria and nutrients available to enter runoff will be the total defecated, and not volatilized, in the area since the last rain.

For large collected manure piles, the bacterial and nutrient release rate will be calculated using Thelin and Gifford's (1983) formulation. Since the release rates were based on small manure piles, they are considered to provide the upper limit for larger manure piles because less bacteria per inch of rainfall would be available to enter runoff.

All nutrients deposited in off-stream watering areas or added to large manure piles since the previous rain are assumed to be available for releasing into runoff except 20% of the defecated nitrogen due to volatilization.

Bacteria and Nutrients Filtered From Runoff

The amount of bacteria, nitrogen, and phosphorus filtered from runoff before reaching the stream will vary depending on length and slope of vegetated buffer, weather and antecedent soil moisture conditions, and available quantities of bacteria, nitrogen, and phosphorus. Maximum filtration from runoff is 100% and will generally decrease to a minimum of 50% for bacteria and 70% for nutrients.

The literature suggests bacteria are filtered out by the soil before reaching the groundwater provided the groundwater is not at the surface. The off-stream watering area will be assumed to be in well drained areas. Large uncovered manure piles may be located in wet areas, but the number of bacteria present will be assumed to provide a bridging effect to keep bacteria from leaching to groundwater.

The literature indicates that the amount of phosphorus leaching to groundwater is varies and is not closely related to the amount applied. There is not enough information available for the river basin in this study to estimate a numerical relationships between applied phosphorus and amount reaching groundwater. Therefore, estimates of phosphorus leaching to groundwater will not be attempted.

Based on literature measuring and estimating soluble nitrogen released from manure piles, 10% of available nitrogen added to large or small manure piles since the previous rain will be assumed to be the maximum amount leached to groundwater.

Nitrogen leaching will only occur when the soil layers are completely saturated and permeable.

CHAPTER 3

DEMONSTRATION OF BEST MANAGEMENT PRACTICES IN SMALL COMMERCIAL AND NON-COMMERCIAL ANIMAL ENTERPRISES

3.1 Abstract

Four cooperating small commercial and non-commercial animal enterprises (SCAEs) implemented Best Management Practices (BMPs) relating to safe manure storage and limited animal access to streams. These enterprises were located next to East Fork Dairy Creek in the Dairy-McKay Hydrological Unit Area. This chapter describes the four enterprises' grazing and manure management practices prior to and after implementing BMPs and the associated costs of the changes in management.

All animal enterprises built covered manure storage facilities with 150 to 180 days capacity. Three animal enterprises implemented off-stream watering areas and denied animal access to East Fork Dairy Creek for watering. Two enterprises implemented vegetated buffer strips to filter runoff from adjacent animal wintering areas. The costs for implementing these practices ranged from 1,972 dollars and 52 hours labor for a two horse operation to 14,259 dollars and 200 hours labor for a 15 horse operation.

3.2 Introduction

Most watersheds neighboring urban areas contain a wide variety of landowners and land management activities, all of which contribute to maintaining or decreasing the water quality. Some of these landowners are SCAEs that raise domestic animals for recreation, food or supplemental income. The impact of these animals on water quality has recently been questioned as water quality standards become more restrictive.

The objective of this project was to obtain four cooperating SCAEs, implement alternative waste management strategies (BMPs) in their animal operations, and to demonstrate these strategies to other SCAEs in the Tualatin River Basin. Four cooperators were obtained and BMPs relating to safe manure storage and limited animal access to streams were implemented. These practices were demonstrated by conducting a tour of the four cooperators operations in September, 1993. The tour was announced in the local paper, and one page fliers were mailed to people that previously contacted the local resource agencies for information or guidance in their own animal operations.

This chapter describes each of the four enterprises' grazing and manure management prior to and after implementing the BMPs, gives a general description of their prior pollution problems, and the costs associated with remediating these problems.

3.3 Management Description of Four SCAEs

Enterprise No. 1

Enterprise No. 1 is a small horse operation bordering the east side of East Fork Dairy Creek. Two full grown horses are raised on 7 acres of pasture, and the pasture is managed without a tractor, plow, or manure spreader. The horses are kept in a barn overnight and allowed to graze during the day. The following is a more formal description of the operation (see Figure 1 in Appendix A).

Livestock - 2 mature horses

Pasture - 5 acres bordering the east side of East Fork Dairy Creek; 2 acres on the hillside close to the house and barn. These pastures are divided by

Dairy Creek Road with 5 acres on the west side and 2 acres on the east side.

Landforms - The 5 acre pasture consists of 4 acres on a floodplain bordering Dairy Creek and 1 acre on a terrace bordering Dairy Creek Road. There is 15 -25 feet of riparian vegetation along Dairy Creek including alder trees, grasses, and various riparian plants. The banks are steep, 6 feet high, and only allow animal access to one area. The slopes of the floodplain and terrace range from 0-3%, but the transition zone between these two areas slopes approximately 40%. All 4 acres of the floodplain pasture is saturated in the winter time, and 2 of these acres typically have 0.5 to 2 inches of water flowing towards the stream. The 2 acre pasture on the east side of the road is on a footslope of the mountains and averages 20% slopes.

PRIOR MANAGEMENT

Prior to implementing the BMPs, manure was collected from the barn and piled. The manure pile was not covered and had not been spread for two years. The pile was located next to the barn and 1000 feet from East Fork Dairy Creek.

The horses had access to the whole 5 acres on the west side of the road during the fall, winter, spring, and parts of the summer. The horses were put on the 2 acres east of the road during short periods of the summer. As mentioned earlier, the 5 acre pasture consisted of 4 acres of saturated soils from November through May with 0.5 to 2 inches of surface water moving towards the creek. Animal access to this area can be considered a direct impact to surface and groundwater during this time period. The horses also had access to 15-25 feet of Dairy Creek for watering during all seasons. Even though this is limited access, the animals could directly impact the stream in all weather conditions.

CHANGES IN MANAGEMENT

Enterprise No. 1 implemented BMPs to mitigate surface and groundwater impacts. One BMP consisted of building a covered manure composting facility (bin) to store and treat collected horse manure. The collecting and composting is done manually. The manure will be spread once a year around trees, in the garden, or on the pastures.

Other implemented BMPs include denying animal access to East Fork Dairy Creek, providing an off-stream watering area, and managing pastures by rotational grazing. An additional 5 foot filter strip was added to the protected riparian vegetation along Dairy Creek. The horses still cross the creek when the owners take them for trail rides. This occurs every two weeks during the summer, but is minimal during the winter. Horses are rotated for grazing to only dry parts of the 5 acre pasture by using cross fencing and a pasture pump in the off-stream watering area. The pasture pump is a Utina M Pasture Pump distributed by Farm Trol Equipment Company of Theresa, Wisconsin. It is located 175 feet from Dairy Creek and pumps water from the creek.

Enterprise No. 2

Enterprise No. 2 raises a variety of animals for food and revenue. The operation includes 4 1/2 acres of pasture and borders both sides of East Fork Dairy Creek. This operation has use of a tractor and manure spreader. The following is a more detailed description of the operation (see Figure 2 in Appendix A).

Livestock - 4 cows averaging 650 pounds and 2 calves averaging 400 pounds in the summer and early fall, 2 cows averaging 600 pounds and 2 calves averaging 400 pounds from November through May (wintering period), 1 boar and 6 sows year round, 25-35 weeners in the spring, after 8-10 weeks then keep 5 feeders for 4 more months, 30 turkeys from May to mid November, 30 egg laying chickens year round, and 100 fryers for April to July.

Pasture - 1 1/2 acres bordering 126 feet of the east side of East Fork Dairy Creek. A barn is located next to this acreage and also borders Dairy Creek. 3 acres of irrigated pasture bordering 350 feet of the west side of East Fork Dairy Creek, a bridge divides the 350 feet into 100 feet extending north and 250 feet extending south

Landforms - The 1 1/2 acres on the east side of the creek are on a terrace landform that averages 0-3% slopes. There is a steep bank 6 feet high by 10 feet wide where this pasture borders the creek. The bank has some riparian vegetation that mainly consists of blackberry bushes. The 3 acres on the west side of the creek are on a floodplain and average 0-3% slopes. Redwood trees and no grass are located along the most northern 50 feet of the creek, blackberry bushes and grass cover the next 50 feet going south to the bridge, and irrigated pasture covers the 200 feet south of the bridge.

PRIOR MANAGEMENT

The 1 1/2 acres on the east side of the creek were used as a wintering area for the animals from mid-fall to mid-spring. Animals were allowed access up to the bank, and the whole 1 1/2 acres remained unvegetated until the growing season. Manure was collected year round from inside and close areas outside the barn. Manure was piled, with no cover, about 30 feet from the creek (20 feet from the bank) and spread twice a year. From mid-fall to mid-spring, the possibility of nutrient and bacteria movement to East Fork Dairy Creek is high due to limited vegetation for filtering and the steep creek bank.

From June 1 to October 15, the 4 cows were left on the 3 acres west of the creek. They were allowed access to all areas next to the creek except the fenced 50 feet of blackberry bushes and grass north of the bridge. However, the cows could only access 75 feet of the creek south of the bridge (due to a steep bank) and 50 feet north of the bridge (underneath redwood trees). The potential for nutrient and bacteria entering runoff to the creek is low in summer due to low amount and frequency of rainfall, but would increase during the rainy season if the animals remained on the pasture. However, animals drinking and defecating in the creek would impact water quality regardless of the weather. All other animals were confined to the 2 acre pasture east of the creek during this period, while the poultry are always confined to the barn.

CHANGES IN MANAGEMENT

A number of BMPs were implemented on the 1 1/2 acre pasture. One BMP implemented was a 15 foot wide vegetated filter strip next to the east bank of East Fork Dairy Creek. This strip was built into a one foot high berm sloping away from the creek, and animals were denied access to it. The filter strip width including the bank is now 25 - 30 feet. Another BMP implemented involved reducing the wintering area size to 1/4 acre, while the other 1 1/4 acres are rotationally grazed during the growing season. The unvegetated wintering area remained next to the vegetated filter strip and edge of the barn.

A 150 day manure storage facility with roof and concrete floor was built. It stores the poultry manure, approximately 1/3 of the animals' manure confined to the 1 1/4 acre pasture in the summer, and all manure collected from the wintering area and inside the barn during the wintering period. The stored manure is spread on the 3 acre pasture west of the creek in the spring.

Two BMPs were implemented on 3 acres west of East Fork Dairy Creek. An off-stream watering area was provided using a water trough filled by the cooperator's domestic water supply. The off-stream watering area is located 50 feet from the creek next to the transition area between the redwood trees and blackberry bushes north of the bridge. In addition, electric fencing denies animal access to the stream and that width varies from 5 to 25 feet.

Enterprise No. 3

Enterprise No. 3 is a small beef cattle operation bordering East Fork Dairy Creek. This operation manages 6 1/4 acres of pasture for rotational grazing using a tractor and manure spreader. The cooperator voluntarily implemented a number of BMPs before our study was conducted. A more detailed description of the operation is given in the following sections (see Figure 3 in Appendix A).

Livestock - 4 to 6 cows averaging 1000 pounds and two calves averaging 500 pounds year round.

Pasture - 6 acres of irrigated pasture east of East Fork Dairy Creek and 1/4 acre of pasture west of East Fork Dairy Creek

Landforms - 3 acres are on a floodplain and 3 acres are on a terrace with both averaging 0-3% slopes. 1/4 acre lies in the transition zone between the floodplain and terrace.

PRIOR MANAGEMENT

All animals stayed in a 1/4 acre wintering area or barn from November through May located 300 feet from the creek. Manure inside the barn and most of the 1/4 acre pasture was collected, piled uncovered 250 feet from the creek, and spread twice a year. From June to October, this wintering area became vegetated and all animals were rotated in the pastures. The animals drank from the creek 3 weeks in the summer when grazing a 1/4 acre pasture west of the creek. However, access was limited to a width of 15 feet.

Remaining stream banks had a 25 foot buffer of trees, riparian vegetation, and grass filter strips. Watering troughs were available in the 6 acre pasture to aid rotational grazing.

Two potential pollution problems needed to be ameliorated. The uncovered manure pile was a long distance from the creek, but was located on a floodplain where soils become saturated in the winter and hold small areas of standing water. This increases potential nutrient and bacteria movement to surface and groundwater. The second problem was the cows access to the creek allowing direct inputs of waste.

CHANGES IN MANAGEMENT

A 150 day manure storage facility with roof and concrete floor were built for the wintering period. Manure is collected from inside and close by the barn on a year round basis. The manure is spread once or twice a year on the 6 acre pasture east of the creek.

Creek access from the 1/4 acre pasture west of the creek was eliminated using a fence. The neighbor's cows, Enterprise No. 2, has a 3 acre pasture west of the creek and adjacent to this pasture. Since an off-stream watering area is available on the 3 acres, Enterprise No. 3 allowed the neighbor's cows graze this 1/4 acre pasture also.

A Utina M Pasture Pump, like the one implemented in Enterprise No. 1, was installed to allow more convenient watering access for rotational grazing on the 6 acre pasture. It was also installed for BMP demonstration purposes in public tours to educate private landowners about off-stream watering devices.

Enterprise No. 4

Enterprise No. 4 is a horse operation that raises and sells horses. The operation borders the west side of East Fork Dairy Creek and has 9 acres of pasture. The horses were kept in a barn or unvegetated dry lots year round. The cooperator used a tractor and will buy a manure spreader after the BMPs are implemented. The following sections give a more elaborate description of the operation (see Figure 4 in Appendix A).

Livestock - 12-20 horses averaging 1000 pounds each.

Pasture - 9 acres of pasture west of Dairy Creek. 4 of these border 1000 feet of East Fork Dairy Creek with 25-50 feet of riparian vegetation, 2 of these border 300 feet of an intermittent stream and small perennial pond. The remaining 3 acres are north of the 2 acre pasture and west of the 4 acre pasture.

Landforms - The 4 acres bordering East Fork Dairy Creek are on a floodplain averaging 0-3% slopes, the 2 acres are on a terrace averaging 3-6% slopes towards the stream and pond, and the 3 acres are between the terrace and floodplain averaging 20% slopes and containing springs.

PRIOR MANAGEMENT

The 4 acre pasture on the floodplain bordering Dairy Creek, 3 acre pasture with 20% slopes, and 1/2 acre pasture on the terrace bordering the intermittent stream were pasture with no animals grazing all year. The remaining 1 1/2 acres of the terrace were unvegetated dry lot areas having no vegetation year round. Nine to fourteen horses stayed in the dry lots, and three to six stayed in the barn year round.

Approximately 90% of the defecated manure in the barn was manually collected three times a week. An estimated 70% of the manure was collected from the dry lots from November through May leaving 30% of defecated manure and associated nutrients and bacteria to enter surface runoff or leach to groundwater. All collected manure was piled on the terrace 200 feet from the stream and 100 feet from the 20% slopes containing springs. The manure was never covered, and transported off the property twice a year.

The presence of springs close to the manure pile suggests the possibility of nutrients and bacteria mixing with surface or groundwater sources.

The intermittent stream had a 10 foot wide vegetated buffer, with slopes of 3-6% slopes, that increased to 30 feet as the stream flows into the small pond. The 30 foot wide buffer had a steep bank with trees and riparian vegetation. A mound of soil 3 feet high and 50 feet long lied next to the steep bank and vegetated buffer. The narrow 10 foot wide buffer is off the cooperator's property and grazed periodically by the neighbor's sheep. A portion, 1/2 acre, of the dry lots borders this narrow buffer and is unvegetated all year. As mentioned earlier, 30% of the defecated bacteria and nutrients in the dry lots potentially enter surface runoff and flow towards the intermittent stream and pond.

CHANGES IN MANAGEMENT

Two BMPs implemented involved constructing a vegetated berm next to the intermittent stream that increases buffer width to 40 feet and denying animal access to the berm. The berm is designed to divert and filter surface runoff and sends the filtered water to the flatter pastured areas. These areas are located farther away from the stream and pond between the 3 and 4 acre pastured areas. The 40 foot buffer will remain vegetated and ungrazed year-round.

A 150 day covered manure composting facility with concrete floor was built. Instead of paying to transport manure off the property, it will be spread on the pastures once or twice a year. The manure will be composted to help prevent the possible spread of pathogenic bacteria.

The size of dry lots was maintained at 1 1/2 acres year round, but reorganized for the 40 foot buffer strip and compost facility. The number of horses on them in the winter remains the same, but the number next to the buffer is reduced to 4 - 8. All pastured areas will be rotationally grazed from June to November, with no manure collected from these areas.

3.4 Costs of Implementing Practices

BMPs are recommended based on potential pollution problems they are designed to mitigate, but landowners decide which practices are economically feasible for their operation. Costs incurred from implementing BMPs for each animal enterprise are given in the following tables. Not included in the tables are subsidies each cooperator received to implement practices and demonstrate their operations for the public tour. Project funds subsidized Enterprise No. 1 with 1,075 dollars, and Enterprises 2, 3, and 4 with 3,000 dollars. A pasture pump was also donated to Enterprise No. 3 for demonstration purposes. Enterprise No. 4 received cost share money from the Agricultural Stabilization and Conservation Service to further subsidize costs for the compost facility's roof, fencework, and pasture renovations. The exact amount of money subsidized was not known when this study was conducted.

Table 3.1. Costs of implementing BMPs for Enterprise No. 1, 1993.

BMPs Implemented	Cost of Materials and Labor ($)	Additional Costs (Hours)
Manure Compost Facility		
Building Materials	928	
Thermometer	24	
Labor		40
Cross Fencing		
Supplies	505	
Labor		2
Off-Stream Watering Device		
Pump	400	
Supplies	40	
Ditcher	75	
Labor		10
TOTAL	1,972	52

Table 3.2. Costs of implementing BMPs for Enterprise No. 2, 1993.

BMPs Implemented	Cost of Materials and Labor ($)	Additional Costs (Hours)
Manure Storage Facility		
Materials, Hired Labor	3,900	
Labor		80
Earthen Berm		
Labor		8
Tractor		8
TOTAL	3,900	88 person, 8 tractor

Table 3.3. Costs of implementing BMPs for Enterprise No. 3, 1993.

BMPs Implemented	Cost of Materials and Labor ($)	Additional Costs (Hours)
Manure Storage Facility		
Materials	1,425	
Ditching, Drainage	250	
Hired Labor	1,728	
Off-Stream Watering Device		
Pump	400	
Pipe and Supplies	120	
TOTAL	3,923	

3.5 Conclusion

Four SCAEs varied in number and types of animals raised. All had similar manure and grazing management practices potentially affecting surface and groundwater and implemented BMPs to reduce this potential. Implemented BMPs included covered manure storage facilities with impermeable floors, off-stream watering areas, denying animal access to streams and excessively wet pastured areas, vegetated filter strips and berms, riparian areas, rotational grazing, and maintaining minimum-sized unvegetated areas in the winter. Costs of implementing these BMPs ranged from 1,972 dollars and 52 hours labor for a two horse operation to 22,793 dollars and 480 hours labor for a 12-20 horse operation. A majority of these costs were subsidized by project funds and cost share funds from the Agricultural Stabilization and Conservation Service. This study was also successful in demonstrating these techniques in a tour of the four operations.

Table 3.4. Costs of implementing BMPs for Enterprise No. 4, 1993.

BMPs Implemented	Cost of Materials and Labor ($)	Additional Costs (Hours)
Manure Compost Facility		
Materials, Hired Labor	12,257	
Labor		100
Water Diversion		
Earth Movement	2,002	
Labor		100
Fencework		
Materials	5,267	
Labor		180
Established New Pasture		
Materials	1,962	
Labor		60
New Access Road		
Materials, Hired Labor	1,305	
Labor		40
TOTAL	22,793	480

CHAPTER 4

DOES A PASTURE PUMP LIMIT DAIRY COWS' WATER CONSUMPTION?

4.1 Abstract

An animal operated diaphragm pump, pasture pump, is an off-stream watering system providing water away from streams and other surface water sources. Off-stream watering systems are BMPs designed to reduce animal use of streams and improve water quality. This paper addresses the questions: How long does it take animals to learn to use the pump? Does the pump limit animals' water consumption? The study compares 27 Holstein dairy heifers' water consumption from an open water trough versus their water consumption from a pasture pump and observes the learning time required to use the pump. Due to the curiosity of these animals, the learning period typically was less than one day. No heifers showed physical signs of dehydration nor were any animals injured. The heifers' water consumption from the pasture pump was not significantly different than water consumption from the water trough.

4.2 Introduction

Many SCAEs allow animal access to streams for watering. Since animal manure is a source of bacteria, nitrogen, and phosphorus that impact water quality, reducing manure deposits in the stream and riparian area is desirable. Off-stream watering areas are

BMPs designed to reduce time animals spend at the stream, reduce defecations in the stream, and improve water quality.

Providing off-stream watering areas for animals usually require one or more watering tanks and fresh water pumped from a household water supply or stream. Given the expense of setting up and maintaining these watering systems, landowners may not change their present practices of allowing animal access to the creeks.

One alternate off-stream watering system is an animal operated diaphragm pump (See figure in Appendix B) and no water tanks. This type of pump, referred to as a pasture pump, has a basin of water (1-2 pints) that animals drink. This basin is partially covered by a rounded lever. For the animal to access the water in the basin, it must push this lever with its nose or muzzle. When the animal releases the lever, the pump pulls water from a pipe and refills the basin. The pump remains primed by the use of a check valve at the end of the pipe. The end of the pipe is placed in the water source (stream, pond, well). This pump design requires no electricity, and the animals control the amount of water pumped.

Among the questions raised by SCAEs are: How long does it take animals to learn to use the pump? Does the pump limit animals' water consumption? Since only one animal can access the pump at a time, would animals drink more water from an open trough or tub than the pasture pump?

The objective of this exercise is to compare 27 Holstein dairy heifers' water consumption from an open water trough versus their water consumption from a pasture pump. These animals' learning time for using the pump will also be observed. The pasture pump used in this study is a Utina M Pasture Pump distributed by Farm Trol Equipment Company of Theresa, Wisconsin.

4.3 Methodology

The 27 heifers averaged 386 kilograms (850 pounds) and were 15 to 16 months old. The heifers were fed silage every morning under a roofed structure. The water trough was within 15 meters of the feeding area, but was not under the roofed structure. The heifers had access to an approximate six acre (2.4 hectare) pasture. The pasture was irrigated as needed.

The water trough had a capacity of 374.5 liters (99 gallons) with surface measurements of 132 by 81 centimeters (52 by 32 inches). The pasture pump was attached to plywood and placed over the water trough when in use. The plywood denied animal access to the water trough, but the pump used the trough's water as the water source.

The heifers were given approximately two weeks of alternating between the pasture pump and water trough before water consumption data were recorded. Learning time and animal behavior were observed during this period.

Water consumption from the water trough and pasture pump were calculated by taking water depth measurements in the trough. Measurements were taken at approximately 0830, 1130, 1430, 1730, and 2030 hours each day. The pump was placed on, or taken off the water trough, at the 1130 hour. The study was conducted from 1130 on July 9 to 1130 on July 23, 1993. The water depth measurements (centimeters or inches of water consumed) were converted to volume by calibrating the water trough. Trough calibrations were conducted by measuring the change in water depth per 23.4 liters of water added. Data collected included the date and time of measurements, depth of water in the tank, daily maximum and minimum air temperature, and any depth of precipitation greater than trace amounts. Any observed factors that could have altered the amount of water consumed by the animals were also noted (weather conditions, irrigating the pastures, etc.).

4.4 Results and Discussion

The learning period for the heifers to use the nose pump was typically less than one day. The short learning period might be due to the heifers' curiosity. A "pecking order" among the cows was created at the pump. Less dominant heifers waited while more dominant ones drank. No heifers showed physical signs of dehydration nor were any animals injured. Two days were needed for less dominant heifers to establish a routine of when to use the pump.

Data were evaluated in two ways. One way reported total daily water consumption from 2030 of one day to 2030 of the next (Table 4.1). Water consumption varied at different times during the day, with maximum amounts consumed following feed times. Since the pump was removed from, or placed on, the trough at 1130 hours, viewing daily water consumption from 2030 to 2030 hours caused two days of data to have questionable accuracy. These days, July 13 and July 19, do not seem to differ greatly from other days. In addition, two errors are noted in Table 4.1. One error was due to the pump losing its prime between measurements, hence water was temporarily unavailable. This may account for the low daily measurement on July 11. This measurement was included in the analysis. The second error occurred on July 14 when no measurements were taken.

The second way data were evaluated reported daily water consumption from 1130 of one day to 1130 of the next day (Table 4.2). Viewing the daily water consumption during this time interval eliminates the problem of the pump being placed on or removed from the trough. However, three days of data were lost due to other problems and are noted as errors in Table 4.2. No measurements were taken for part of July 13 and July 14. The July 21 measurements do not include the normal amount of water consumed since the heifers were fed late. These three days were not included in the analysis.

Table 4.1. Daily water consumption from one pasture pump (pump on) or one open water trough (pump off) by twenty seven Holstein dairy heifers from July 9 to July 22 (2030 to 2030 hours).

Date (July 9 to 22, 2030 to 2030)	Liters Consumed	Pump	* Errors	Daily Temperature High, Low
10-July	638	on		73,57
11-July	360	on	* error	73,57
12-July	809	on		66,55
13-July	494	on to off		66,59
14-July	---	off	* error	68, 59
15-July	628	off		68,59
16-July	424	off		66,59
17-July	398	off		68, 59
18-July	525	off		74,57
19-July	632	off to on		69,60
20-July	605	on		67,59
21-July	418	on		67,58
22-July	473	on		65,60

Table 4.2. Daily water consumption from one pasture pump (pump on) or one open water trough (pump off) by twenty seven Holstein dairy heifers from July 9 to July 23 (1130 to 1130 hours).

Date (July 9 to 23, 1130 to 1130)	Liters Consumed	Pump	* Errors	Daily Temperature High, Low
9-July	491	on		74,46
10-July	478	on		73,57
11-July	737	on		73,57
12-July	587	on		66,55
13-July	---	off	* error	66,59
14-July	---	off	* error	68, 59
15-July	485	off		68,59
16-July	358	off		66,59
17-July	475	off		68, 59
18-July	600	off		74,57
19-July	707	on		69,60
20-July	513	on		67,59
21-July	---	on	* error	67,58
22-July	738	on		65,60

Due to the small number of data sets for comparison and the large variability between days suggesting non-normal distribution functions, the data were analyzed qualitatively rather than quantitatively. Tables 4.3 and 4.4 show daily, average, and standard deviation of water consumption for comparing the pasture pump to the open water trough. Days when the pump was changed from on to off were analyzed as on days, and the opposite situations were analyzed as off days. The average water consumed from the pasture pump is higher than the amount consumed from the water trough, indicating the pasture pump does not limit the animals' water consumption. In addition, no significant amounts of water being spilled or wasted from the pasture pump were observed.

Table 4.3. Water consumption data for twenty seven Holstein dairy heifers from July 9 to July 22 (2030 to 2030 hours) and their associated daily average and standard deviation.

Pump On/Off	Liters Consumed	Pump On/Off	Liters Consumed
on	638	off	628
on	360	off	424
on	809	off	398
on	494	off	525
on	605	off	632
on	418	---	---
on	473	---	---
Average =	542	Average =	521
Standard Deviation =	153	Standard Deviation =	110

Data were collected during the summer of 1993 when daily maximum and minimum air temperatures ranged from 65 to 74°F (18 to 23°C) and 46 to 60°F (8 to 16°C), respectively (Appendix B includes raw data). No correlation between daily maximum and minimum temperatures and water consumption were determined. Most of the days were cloudy, overcast, and cool. Only one day (July 21) had rainfall greater than

0.1 inches (0.25 cm) which was reported as 0.41 inches (1.04 cm) The July 21 measurement of daily water consumed (Table 4.1) did not seem affected by the rainfall. The pasture was irrigated on July 15,16, and 19. However, water consumption measurements did not seem affected.

Table 4.4. Water consumption data for twenty seven Holstein dairy heifers from July 9 to July 23 (1130 to 1130 hours) and their associated daily average and standard deviation.

Pump On/Off	Liters Consumed	Pump On/Off	Liters Consumed
on	491	off	485
on	478	off	358
on	737	off	475
on	587	off	600
on	707	---	---
on	513	---	---
on	738	---	---
Average =	607	Average =	480
Standard Deviation =	118	Standard Deviation =	99

4.5 Conclusion

These 27 Holstein dairy heifers' water consumption from a pasture pump was not significantly differently than water consumption from a water trough. Therefore, the dairy cows' water consumption is not limited when using a pasture pump. The heifer's learning period for activating the pump was typically less than one day. It is speculated that two days are required for less dominant heifers to establish a routine of when to use the pump.

CHAPTER 5

OFF-STREAM WATERING AREAS TO REDUCE TIME ANIMALS SPEND AT A STREAM AND IMPROVE WATER QUALITY

5.1 Abstract

Two studies evaluated the effectiveness of off-stream watering areas to reduce time animals spend at a stream without denying access to the stream. The studies were conducted in two SCAEs described in Chapter 3. One study, located in Enterprise No. 2, measured the time four beef cows spent at a stream with and without an off-stream watering area. The other study, located in Enterprise No. 1, measured two full grown horses' water consumption from a pasture pump (off-stream watering device) with and without creek access.

No statistically significant difference existed for the time four cows spent at the stream with and without an off-stream watering area available. The average time all four cows spent at the stream was reduced from 60 minutes per day to 15 minutes per day. No statistically significant difference existed in the two horses' water consumption from the pasture pump with and without creek access, as long as the pump was located in the horses' normal path towards the creek. Water consumption from the pasture pump decreased 17% when the horses had creek access. However, a significant difference existed in water consumption from the pasture pump with and without creek access when the horses were on wet pasture and grazing between the pump and creek. Average water

consumption from the pump decreased 53% when the horses had creek access and grazing between the pump and creek.

5.2 Introduction

SCAEs often allow animal access to creeks for watering causing water quality impacts to the associated river basin. To reduce water quality impacts, regulatory agencies encourage implementing a BMP that denies animal access to creeks and provides off-stream watering areas. Implementation costs of this practice may seem small for one enterprise, but the implementation costs for all enterprises in a watershed could be considerable. To reduce costs, the effectiveness of supplying off-stream watering areas to lure animals out of the stream, without denying access to the creek, should be considered.

This chapter's objective is to evaluate effectiveness of off-stream watering areas in reducing time animals spend at a stream without denying access. Two similar studies were conducted on two SCAEs described in Chapter 3, Enterprises No. 1 and 2.

5.3 Methodology

One study involved monitoring the time four beef cows (averaging 283 kilograms) spent within 4.6 meters (15 feet) of a stream with and without an off-stream watering area available. This operation is described in Chapter 3 and illustrated in Appendix A as Enterprise No. 2. A water trough was the off-stream watering device located approximately 23 meters (75 feet) from the creek access area. The water trough was not located in the animals' normal path to the creek. The cows grazed an adjacent pasture and were closer to the point of creek access than the water trough.

A CR10 datalogger, distributed by Campbell Scientific, Inc., and two light beam counters counted the minutes the animals spent at the stream. When the light beams were broken, the datalogger recorded the date, time, and direction the cows were moving in relation to the stream (raw data given in Appendix C). A walkway, or chute, constructed out of gates allowed one animal to enter or leave the stream area at a time. However, the stream area was approximately 9.3 square meters (100 square feet) and allowed all four cows to loiter and have stream access at the same time. The pasture in this area was thoroughly grazed prior to the study.

The study was conducted from August 7, to September 18, 1993. Data were collected for 17 continuous days when the animals had no off-stream watering area and had to water at the creek. A period of nine days were allowed for the cows to adjust to watering at the creek before data were collected. After the 17 days of collection, an off-stream watering area was provided in addition to the creek access, and six days were allowed for the cows to adjust to the available water sources. Then, 11 continuous days were monitored with cows having access to both the creek and off-stream watering area. Daily high and low temperatures from the Hillsboro airport were also recorded. The airport is lower in elevation than the study site.

The second study involved monitoring two full grown horses' water consumption from an off-stream watering device. This operation is described in Chapter 3 and illustrated in Appendix A as Enterprise No. 1. The off-stream watering device was an animal operated diaphragm pasture pump, Utina M Pasture Pump distributed by Farm Trol Equipment Company of Theresa, Wisconsin, as described in Chapter 4 and illustrated in Appendix B. The pump was placed approximately 175 feet from the point of creek access. The pasture pump pulled water from a calibrated water trough allowing the consumption of water to be monitored. The horses always had access to the pasture pump, but never had access to the water trough. The calibrated water trough was located near the stream and in shade.

Water consumption was monitored for three different pasture management scenarios. For the control scenario, the horses accessed only the pump and grazed the wet pasture and drier pasture described in Chapter 3 and illustrated in Appendix A. One pasture contained more moisture and was located between the pump and creek, while the other pasture was drier and adjacently located to the pump. For the second scenario, the horses accessed both the creek and pasture pump and grazed the wet pasture. For the third scenario, the horses accessed both the creek and pasture pump and grazed the drier pasture.

The control situation was monitored for 30 days, wet pasture situation for seven days, and drier pasture situation for eight days. The study was conducted from August 4, to September 17, 1993. Daily maximum and minimum temperatures and pan evaporation were also recorded. The temperature data were recorded at the Hillsboro Airport, and the pan evaporation data were recorded at the North Willamette Research and Experiment Station. Both of these locations were lower in elevation than the study area. Pan evaporation data were collected to estimate the amount of water evaporated from the calibrated tank per day.

5.4 Results and Discussion

When the cows had no off-stream watering area, the time four cows spent within 4.6 meters of the stream averaged 60 minutes with a standard deviation of 29 minutes (Table 5.1). When given the choice of watering areas, the total time they spent near the stream reduced to an average of 15 minutes with a standard deviation of 18 minutes.

A Wilcoxon Two Sample Rank Test was performed on the data. The ranking of the data is shown in Table 5.1, while the hypothesis test and results are shown in Table 5.2. This test is non-parametric and does not pivot on normality. Since the data contained outliers suggesting a non-normal distribution function, this type of test was chosen. The mean time the four cows spent at the stream with the option of using the water trough is significantly different than without the water trough option. These results were significant at the 99% confidence level using an alpha of .01. No correlation between daily maximum and minimum temperatures and time spent near the stream was determined.

The time of day the four cows entered the stream zone was observed using the data. For most days, cows entered and exited the stream zone over a twelve hour period. This is consistent with Miner et al.'s (1992) assumptions that no animals entered or exited the stream zone from sundown to sunrise the following day.

Table 5.1. Enterprise No. 2, data for the time 4 cows drink from a stream with and without an off-stream watering area (water trough) available.

Cows Access Stream Only			Cows Access Both Stream and Trough		
	Minutes at Stream			Minutes at Stream	
Day	Minutes	Rank	Day	Minutes	Rank
8/22/93	84	27	9/14/93	51	19
8/23/93	64	22	9/15/93	9	5.5
8/24/93	153	28	9/16/93	11	7.5
8/25/93	66	23	9/17/93	14	9
8/26/93	28	10	9/18/93	9	5.5
8/27/93	37	12	9/19/93	47	18
8/28/93	72	24	9/20/93	5	4
8/29/93	30	11	9/21/93	0	1
8/30/93	57	21	9/22/93	2	2
8/31/93	41	13	9/23/93	11	7.5
9/1/93	76	25.5	9/24/93	3	3
9/2/93	45	16		Rank Sum =	82
9/3/93	56	20			
9/4/93	44	14.5			
9/5/93	76	25.5			
9/6/93	46	17			
9/7/93	44	14.5			
Average =	59.94		Average =	14.73	
Std.Dev =	29.27		Std.Dev =	17.50	
			% reduction	75	
Cows drink from creek (% of time) =				25	

Table 5.2. Wilcoxon 2 Sample Rank Test analyzing if a significant difference exists between time four cows spend at a stream with and without an off-stream watering area available.

Hypothesis Test:

Ho: u1 = u2
H1: u1 < or > u2
where:
u1 is the mean minutes at stream with stream and trough access
u2 is the mean minutes at stream with stream access only

Test Analysis

T1= sum of ranks = 82
T2= n1(n1 + n2 + 1) - T1 = 237
where:
n1 = number of observations for minutes at stream with stream and trough access.
n2 = number of observations for minutes at stream with stream access only

at alpha = .01 level, T is 105 (Snedecor and Cochran, 1989)
T2 is greater than T at this level
Therefore, mean minutes at the stream with trough option is significantly lower than minutes at stream without trough option at an alpha = .01 or 99% confidence level

For the second study, daily water consumption of two full grown horses from a pasture pump averaged 24.4 liters (6.46 gallons), 11.6 liters (3.06 gallons), and 20.3 liters (5.35 gallons) under the control, wet pasture, and drier pasture situations (Table 5.3). The standard deviations for these measurements were 13.4, 7.54, and 8.38 respectively. Based on water consumption from the pump under the control condition, the percent reduction in water consumption from the pasture pump was 53% and 17% for the wet and drier pasture situations respectively.

If the data are adjusted for evaporation, daily water consumption from the pump averages 21.4, 8.26, and 16.4 liters for the control, wet, and drier pasture situations respectively (Table 5.3). The standard deviations for these measurements are 13.3, 5.98, and 8.85 for the control, wet, and drier pasture situations. Percent reduction in water consumption from the pasture pump was 61% and 23% for the wet and drier pasture situations respectively. Daily evaporation adjustments for the calibrated water tank were the daily pan evaporation rate multiplied by 0.75. Two days of recorded water consumption for the control became negative when these adjustments were used. These days were analyzed as zero consumption days.

Table 5.3. Enterprise No. 1, water consumption data for 2 horses drinking from a pasture pump when creek access is and is not available.

No Creek Access

	Liters	Gallons	Adjusted Liters	Adjusted Gallons
Average =	24.4	6.46	21.4	5.65
Std. Dev	13.4	3.55	13.3	3.50
Horses Drink from Pump (%) =	100		100	

Creek Access & Wet Pasture

	Liters	Gallons	Adjusted Liters	Adjusted Gallons
Average =	11.6	3.06	8.26	2.18
Std. Dev	7.54	1.99	5.98	1.58
% reduction	0.53		0.61	

Creek Access & No Wet Pasture

	Liters	Gallons	Adjusted Liters	Adjusted Gallons
Average =	20.3	5.35	16.4	4.33
Std. Dev	8.38	2.21	8.85	2.34
% reduction	0.17		0.23	

Analyses of variance were conducted for the recorded and adjusted water consumption data (Tables 5.4 and 5.5). There was sufficient evidence to conclude that water consumption from the pasture pump under the wet pasture scenario was significantly different (P-value = 0.0469) from the control (Table 5.4). There was insufficient evidence to conclude that water consumption from the pasture pump under the drier pasture scenario was significantly different (P-value = 0.4102) from the control (Table 5.5). The same results were found for the adjusted data, but the P-values lowered to 0.0157 and 0.3224 for the wet pasture and drier pasture scenarios respectively. No discernible relationship existed between daily maximum and minimum temperatures and water consumption.

5.5 Conclusion

This study and Miner et al. (1992) confirm that off-stream watering areas reduce the time cows spend at a stream. The pasture pump analysis indicates increased effectiveness of off-stream watering areas located in animals' normal path to the stream. The analysis estimating the time four cows spend at the stream with an off-stream watering area did not address this different level of effectiveness. However, it indicated watering areas slightly off the cows' normal path to the creek were still effective in reducing time the cows spent at the stream. Given the variability between animal sizes and types, it is difficult to extract standard averages for time animals spend at the stream or amount of water consumed when an off-stream watering area is available.

Table 5.4. Enterprise No. 1, analysis of variance between water consumption from a pasture pump by 2 horses when creek access is and is not available and pasture conditions are wet.

Anova: Single-Factor
Creek access and wet pasture
Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	30	733	24.4	181
Column 2	5	58	11.6	56.8

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	705.8	1	705.8	4.261	0.04693	4.139
Within Groups	5467	33	165.7			
Total	6172	34				

Anova: Single-Factor
Creek access and wet pasture (Adjusted for Evaporation)
Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	7.00	57.9	8.26	35.7
Column 2	30.00	642	21.4	176

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	978.5	1	978.5	6.455	0.01565	4.121
Within Groups	5305	35	151.6			
Total	6284	36				

Table 5.5. Enterprise No. 1, analysis of variance between water consumption from a pasture pump by 2 horses when creek access is and is not available and pasture conditions are not wet.

Anova: Single-Factor
Creek access and no wet pasture
Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	30	733	24.4	181
Column 2	8	162	20.3	70.2

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	110.5	1	110.5	0.6943	0.4102	4.113
Within Groups	5731	36	159.2			
Total	5841	37				

Anova: Single-Factor
Creek access and no wet pasture (Adjusted for Evaporation)
Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	30	642	21.4	176
Column 2	8	131	16.4	78.3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	157.7	1	157.7	1.007	0.3224	4.113
Within Groups	5639	36	156.6			
Total	5797	37				

CHAPTER 6

PREDICTION OF MONTHLY RUNOFF FREQUENCY FOR THE DAIRY-MCKAY HYDROLOGICAL UNIT AREA

6.1 Abstract

The United States Soil Conservation Service's method for determining depth of runoff based on curve numbers is used to predict frequency of runoff for each month of the year from different land uses in the Dairy-McKay Hydrological Unit Area. Land uses analyzed include impermeable and permeable urban areas, pasture, row crops, small grain, and forested. Daily precipitation data from 1948 to 1991 reported at Hillsboro and Scoggins Dam represent precipitation patterns for the sub-basin. After the required depth of rainfall to produce runoff is determined for each month of the year and land use, the frequency of runoff is calculated for the two wettest water years, two driest water years, and the average water year for the data period. The months with the highest frequency of runoff are November through March for the wet and average water years and November through January for the dry water years. Each land use and predicted runoff frequency for each month of the year can be used to develop nonpoint pollution control strategies.

6.2 Introduction

The Dairy-McKay Hydrologic Unit Area (H.U.A.) is a sub-basin of the Tualatin River watershed that drains into the Willamette River of Oregon. Extensive research is being conducted in the H.U.A. to analyze the impacts of various land uses on increasing the total loads of phosphorus, nitrogen, and bacteria in the Tualatin River. An integral part of this research is to predict frequency of runoff associated with different rainfall amounts for the sub-basin. The frequency of runoff and estimates of phosphorus, nitrogen, and bacteria loading rates from different land uses in the Dairy-McKay H.U.A. could be used to predict relative amounts of nutrient runoff, determine the focal points for pollution abatement, and develop a pollution control strategy. The objective of this chapter is to calculate and predict the frequency of runoff for each month of the year from various land uses in the Dairy-McKay H.U.A. using daily rainfall data from 1948 to 1991.

6.3 Methodology for Predicting Runoff

Surface runoff occurs when rainfall intensity exceeds the infiltration capacity (or rate) of the top soil layers causing water to travel on the surface to the stream. The amount of rainfall required to initiate surface runoff and depth of runoff depend on rainfall intensity, the soil's infiltration rate, and the soil's moisture holding capacity. Land uses affect the soil's infiltration rate and moisture holding capacity by altering the soil's vegetation cover and surface drainage pathways. This analysis attempts to account for these land use affects.

One of the most commonly used methods for determining runoff is the United States Soil Conservation Service's (SCS) method (SCS, 1964). This method was developed using storm data collected from small watersheds and attempts to account for different land uses and soil moisture conditions by using runoff curve numbers (Schwab et al., 1966; Bedient & Huber, 1992). Runoff is calculated by:

$$Q = (P-.2S)^2 / (P + 0.8S)$$

where Q = direct surface runoff in inches

P = storm rainfall in inches

S = potential abstraction (maximum potential difference between rainfall and runoff in inches).

The SCS defines the relationship between S and curve numbers(CN) as:

$$S = [(1000)/CN] - 10$$

where CN = curve number varying from 0 to 100 (SCS, 1964).

The CN is selected based on land uses, soil types and their hydrologic characteristics (well drained, plastic and swells, etc.), and antecedent moisture conditions (Bedient and Huber, 1992).

Curve numbers that apply to the Tualatin River Basin were suggested for six different land uses and month of the year (Table 6.1; Miner, 1993). The land uses do not represent all land uses in the Dairy-McKay H.U.A., but could indicate the likelihood of runoff carrying sediment and other suspended contaminants into the Dairy-McKay system. These numbers attempt to relate curve numbers with different land uses and seasonality of the area. Curve numbers are higher during winter months because of high soil moisture storage and low evapotranspiration rates. Conversely, these numbers are lower during summer months due to low soil moisture storage and high evapotranspiration rates. In addition, the likelihood of rainfall that satisfied soil moisture capacity a preceding day is higher during the winter months and is expressed by higher curve numbers.

6.4 Estimate of Required Rainfall to Produce Runoff

The rainfall required to produce runoff is calculated by solving the SCS's equations using a given runoff depth (Q) and curve number. This equation is:

$$P = .5\{(0.45 + Q) - [(0.4S + Q)^2 - 4(0.04S^2 - 0.8SQ)]^{.5}\}$$

For comparison, the rainfall required to produce .01, .10, and .20 inches (.025, .25, and .51 cm.) of runoff per curve number was calculated (Table 6.2).

Table 6.1. Proposed runoff curve numbers for different land uses in the Tualatin River Basin.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
January	97	95	90	90	90	85
February	97	95	90	90	90	85
March	97	95	90	90	90	85
April	95	90	85	90	85	80
May	95	90	80	90	85	75
June	93	85	80	85	80	75
July	93	85	75	85	80	70
August	93	85	75	85	85	70
September	93	90	80	85	85	75
October	95	90	80	90	85	80
November	97	95	90	90	90	85
December	97	95	90	90	90	85

Table 6.2. Estimate of daily rainfall to produce .01, .10, and .25 inch (.025, .25, and .51 cm) runoff based on the SCS method (SCS, 1964).

	Inches of Runoff		
Curve Number	.01	.10	.25
100	.01	.10	.25
97	.011	.29	.49
95	.037	.39	.61
93	.069	.48	.73
90	.122	.61	.89
85	.225	.83	1.15
80	.346	1.05	1.43
75	.489	1.3	1.71

The depths of daily rainfall required to produce 0.10 inches (.25 cm) runoff for each land use and month were calculated (Table 6.3). This calculation assumes the SCS method gives a daily rainfall value to use with daily rainfall data from the area. However, the SCS method was designed for storm rainfall values and assumes that larger storms exceed soil infiltration rates. Therefore, using the SCS method for daily rainfall values instead of storm values may increase the error in predicting runoff values.

Table 6.3. Inches of daily rainfall estimated to produce 0.10 inch (0.25 cm) runoff from different land uses in the Tualatin River Basin.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
January	0.29	0.39	0.61	0.61	0.61	0.83
February	0.29	0.39	0.61	0.61	0.61	0.83
March	0.29	0.39	0.61	0.61	0.83	1.05
April	0.39	0.61	0.83	0.61	0.83	1.05
May	0.39	0.61	1.05	0.61	0.83	1.30
June	0.48	0.83	1.05	0.83	1.05	1.30
July	0.48	0.83	1.30	0.83	1.05	2.03
August	0.48	0.83	1.30	0.83	0.83	2.03
September	0.48	0.61	1.05	0.83	0.83	1.71
October	0.39	0.61	1.05	0.61	0.83	1.05
November	0.29	0.61	0.83	0.61	0.61	0.83
December	0.29	0.39	0.61	0.61	0.61	0.83

6.5 Prediction of Monthly Runoff Frequency

The prediction of monthly runoff frequency for land uses in the Dairy-McKay H.U.A. used daily rainfall data recorded in Hillsboro and Scoggins Dam from 1948 to 1991 and the daily rainfall estimates to produce runoff provided in Table 6.3. The Hillsboro station is located at 160 feet mean sea level and represents the lower elevations, while the Scoggins Dam are located at 360 feet mean sea level and represents the higher elevations. The data available from Scoggins Dam are only from 1973-1985, but are in close proximity to the Dairy-McKay basin and the most representative daily precipitation data available for higher elevations.

First, monthly data were separated into water years, and the two wettest years and two driest years were selected based on their cumulative rainfall. The two wettest water years were 1982 and 1973, and the two driest water years were 1963 and 1976. Critical depths of rainfall that produce runoff for each land use (Table 6.3) were used to evaluate daily precipitation data for each of these years. The percentage of days rainfall exceeds these critical levels and cause runoff was determined for each month (See Appendix D).

The most critical period for both Scoggins Dam and Hillsboro is from November to March, with Scoggins Dam having higher percentages. For the dry water years, no obvious critical period exists.

For comparison to wet and dry water years, average water years were determined for Hillsboro and Scoggins Dam using the number of days rainfall exceeds different critical levels for each month. These number of days were used to calculate an average percentage of days rainfall exceeds different critical levels for each month of the year over the data period. These months and associated percentages represent the average water year (Appendix D). As compared to the wet water years, the average water years provide lower percentages of days producing runoff from November to March and higher percentage of days the other months. As compared to the dry water years, the average water years show a more even distribution of percentages of days producing runoff. The dry water years randomly had months with higher and lower percentages of days producing runoff.

Using the daily rainfall estimates to initiate runoff from different land uses (Table 6.3), the percentage of days rainfall produces runoff was calculated for each month of the five water years (Appendix D). The pasture and row crops land uses could represent pastured and unvegetated wintering areas in SCAEs, respectively. The pastured areas show higher potential for runoff from November to March during wet and average water years, while row crop areas show higher potential from October to April for the same years. BMPs designed to decrease nutrients and bacteria from entering runoff and leaching to groundwater would be most useful during these months. This also indicates that manure should be spread in pastures after March. Since indirect inputs would be minimal from April to October, BMPs designed to decrease direct pollution inputs to streams would be the most beneficial practices to implement.

CHAPTER 7

ANALYSIS OF FOUR SMALL COMMERCIAL AND NON-COMMERCIAL ANIMAL ENTERPRISES FOR REDUCING WATER QUALITY IMPACTS

7.1 Abstract

Off-stream watering areas with animal access to creeks and covered manure storages are analyzed for their effectiveness in reducing nitrogen, phosphorus, and bacterial loads entering the stream and groundwater from small commercial and non-commercial animal enterprises (SCAEs). These analyses are conducted for the four SCAEs described in Chapter 3. In addition, the basin-wide water quality improvements from implementing these practices in all SCAEs in the Tualatin River Basin are discussed.

Off-stream watering areas provide a 75% reduction in bacteria and nutrients entering the stream for days with no rain. The reduction decreases with increasing amount and frequency of rain due to bacteria and nutrients entering the stream from surface runoff. If all bacteria and nutrients kept from entering the stream are placed in the off-stream watering area, there is potential for nitrogen to leach to groundwater under winter rain and saturated soil conditions. The greatest amount of nitrogen leaching towards groundwater is assumed to be 10% of the unvolatilized nitrogen defecated in the off-stream watering area.

Covered manure storages provide the greatest reduction (60% and 30% for the two test sites) in bacterial and nutrient stream water quality impacts for winter days of rain following a previous day of rain. Covered manure storages eliminate nitrogen impacts on

groundwater quality under winter rain and saturated soil conditions for all enterprises. The greatest amount of nitrogen leaching towards groundwater from an uncovered manure pile is assumed to be 10% of the nitrogen applied to the pile since the previous rain.

Based on the present water quality impacts of all SCAEs in the Tualatin River Basin allowing animals stream access, off-stream watering areas potentially reduce this impact by 21% for summer rain, summer no rain, and winter no rain days. Based on the present water quality impacts of all SCAEs in the Tualatin River Basin that collect and pile animal manure, covered manure storages potentially reduce the stream water quality impacts by 26% and nitrogen leaching to groundwater by 4% for winter rain days following previous days of rain.

7.2 Introduction

Off-stream watering areas and covered manure storages are two BMPs designed to reduce bacterial and nutrient loads entering surface water or leaching to groundwater from animal enterprises. Resource agencies in Oregon educate, assist, and encourage SCAEs in voluntarily implementing these BMPs to reduce their water quality impacts. These resource agency programs introduce a variety of questions; How effective are these practices in reducing bacteria, nitrogen, and phosphorus loads into streams and groundwater for different weather conditions? What are the potential water quality improvements for watersheds if SCAEs implement these practices? Addressing these issues would assist resource agencies in developing, monitoring, and evaluating nonpoint source pollution mitigation programs.

This chapter's objectives are to:

1. estimate effectiveness of off-stream watering areas (with animal access to streams) and covered manure storages (150 and 180 day

capacity) in reducing nitrogen, phosphorus, and bacterial loads to streams and groundwater, and

2. discuss potential reductions in nitrogen, phosphorus, and bacterial loads to streams and groundwater from all SCAEs in the Tualatin River Basin.

These practices will be analyzed individually under different weather conditions and seasons for the four SCAEs described in Chapter 3. Potential basin-wide reductions will be based on Miner et al.'s (1993) estimate of the extent of animal raising and manure handling techniques in Washington County.

7.3 Methodology for Evaluating Effectiveness

Effectiveness of off-stream watering areas or covered manure storages is equivalent to percent of nutrients and bacteria reduced from entering the stream and groundwater due to the implemented practice. Effectiveness will also be referred to as percent effectiveness.

The procedure for evaluating effectiveness involves four main steps. First, changes in the nitrogen, phosphorus, and bacteria distributed daily over the land and deposited in streams are quantified. Second, the portions of these quantities available to enter surface runoff and leach towards groundwater sources are estimated. This is accomplished by calculating bacterial die-off and nutrients lost due to on-site conversions. Third, the quantities of nutrients and bacteria filtered from surface runoff or top soil layers are estimated for different weather and antecedent soil moisture conditions In addition, bacteria and nutrients entering the stream and groundwater over 30 days are calculated for these conditions. Finally, the effectiveness of the off-stream watering area or covered manure storage in reducing nutrients and bacteria entering the stream or groundwater sources is estimated for different weather conditions. Effectiveness equals the change in stream or groundwater inputs, divided by the original inputs, and multiplied by 100.

Weather conditions analyzed include rain-days and no-rain-days during the summer and winter seasons. There are two summer scenarios consisting of a no-rain-day and a day with 1.30 inches (3.30 cm) rain. The antecedent soil moisture conditions for both scenarios are dry with no rain events in the previous thirty days. There are three winter scenarios consisting of a no-rain-day, a day with 0.61 inch (1.5 cm) rain, and a day with 0.89 inch (2.3 cm) rain. The antecedent soil moisture conditions for both scenarios are near saturation (no rain events for the past three days) and saturated (rain event the previous day). The days with 1.30 and 0.61 inch rain are assumed to cause 0.10 inch (0.25 cm) surface runoff for pasture conditions, while the day with 0.89 inch rain is assumed to cause 0.25 inch (0.64 cm) surface runoff. These assumptions are explained in Chapter 6.

7.4 Off-Stream Watering Areas

Off-stream watering areas lure animals from the stream which reduces direct stream inputs and redistributes defecated bacteria and nutrients over a larger land area. Animal distribution is measured by estimating the time animals spend at different areas of the pasture or stream. Two studies in Chapter 5 measured the effectiveness off-stream watering areas and devices had on reducing time animals spent at the stream for Enterprises No. 1 and 2. Based on these studies, this analysis assumes 75% reduction in time animals spend at the stream for Enterprise No. 1 and 80% reduction in time for Enterprise No. 2 following the implementation of an off-stream watering area.

The beef cow study in Enterprise No. 2 yielded an average of 60 minutes per day the four cows spent at the stream with no off-stream watering area available. Based on twelve defecations per day over a twelve hour period, one defecation per day would be deposited at the stream (assumptions stated in conclusion of Chapter 2). Implementing the off-stream watering area with a water trough reduces the average time to 15 minutes per day for the four cows. This would yield one defecation every four days at the stream. This analysis assumes that the cows' time at the stream does not change with weather conditions and seasons, and the four cows are on the pasture all year.

The time the two horses from Enterprise No. 1 spend at the stream is assumed to be similar to two cows or 30 minutes a day when no off-stream watering area is available. This yields one defecation every other day at the stream. The horse study observed that allowing creek access when an off-stream watering area and device was available caused the water consumption at the device to decrease 20%. This result occurred as long as the watering device was in the horses' normal path to the creek. Providing an off-stream watering area with a pasture pump reduces the time horses spend at the stream by 80% and decreases the number of defecations in the stream zone to one every ten days.

As stated in the conclusion of Chapter 2, providing off-stream watering areas cause defecations in these areas to increase the same number that were decreased from the stream. Therefore, the four cows would defecate three times every four days and the horses would defecate four times every ten days in their off-stream watering areas. Since animal access to streams is not restricted when implementing this practice, grazing along the stream and between the stream and off-stream watering areas will not change.

Enterprise No. 2, the beef cow operation, managed two 500 pound (227 kg) and two 750 pound (340 kg) beef cows on approximately 3 acres (1.2 hectares) yielding 0.83 animal units per acre (2.1 animal units per hectare). Therefore, the average defecation per cow deposited in the stream or off-stream watering area is 3.1 pounds (1.4 kg). The average number of fecal coliforms and fecal streptococci per defecation is 3.3×10^8 and 1.8×10^9 respectively. The average amount of nitrogen and phosphorus per defecation is 0.018 pounds (8.2 grams) and 0.0058 pounds (2.6 grams) respectively.

Enterprise No. 1 managed two horses averaging 1000 pounds (450 kg)on five acres (2 hectares) yielding 0.40 animal units per acre (1 animal unit per hectare). The average defecation per horse deposited every other day in the stream or off-stream watering area is 3.8 pounds (1.7 kg). The average number of fecal coliforms and fecal streptococci per defecation is 2.1×10^7 and 1.1×10^{10} respectively. The average amount of nitrogen and phosphorus per defecation is 0.023 and 0.0038 pounds (10 and 1.7 grams) respectively.

For comparison to published bacterial water quality standards, the number of fecal coliforms per 100 ml is calculated using a flow of 10 cubic meters per minute and one average defecation from a cow in Enterprise No. 2. Assume the defecation is placed into a box of 10 cubic meters of water, 95% of the fecal coliforms settle out, and the water is well mixed (settling rate from Biskie et al., 1980). If a water sample was taken from the box as it traveled down stream, the fecal coliform concentration would be 7.7 per 100 ml. Biskie et al. (1988) estimated 1.2×10^7 fecal coliforms were defecated into a rangeland stream with 6 cubic meters per minute flow, and the resulting concentration translated to 0.13 fecal coliforms per 100 ml. Recall the standard fecal coliform concentration for recreation water is 200 per 100 ml.

Assumptions pertaining to the management of the land between off-stream watering areas and streams are mentioned in the conclusion of Chapter 2. Since it is very difficult to estimate the number of defecations entering the stream versus the stream bank, this analysis assumes all defecation are directly deposited in the stream.

Summer Weather Scenarios

During a summer day with no rain and dry antecedent soil moisture conditions, no rain event for the past 30 days, no runoff occurs and the bacteria, nitrogen, and phosphorus reduced from entering the stream are determined by direct stream inputs. In addition, no nitrogen will leach to groundwater. Therefore, implementing off-stream watering areas in Enterprises No. 1 and 2 reduce the nitrogen, phosphorus, and bacteria defecated in the stream daily by 80 and 75% respectively. Since no runoff occurs, 80 and 75% also represent percent effectiveness of the implemented practices as they relate to stream reductions. Since no nitrogen leaches to groundwater, implementing this practice has no change and no percent effectiveness relating to leaching reductions to groundwater for both enterprises. The 30 day accumulations of bacteria, nitrogen, and phosphorus reaching the stream from Enterprises No. 1 and 2, with and without off-stream watering areas, are shown in Table 7.1.

Table 7.1. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) entering the stream from Enterprises No. 1 and 2 for a summer day with no rain.

30 Day Weather Scenarios	No Off-Stream Watering Area	Off-Stream Watering Area
Summer Dry	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)
Enterprise No. 1	0.32, 160, 150, 26	0.064, 32, 31, 5.4
Enterprise No. 2	9.8, 55, 240, 77	2.6, 14, 59, 20

A summer day with 1.30 inches (3.30 cm) rain is estimated to cause 0.10 inch (0.25 cm) surface runoff. Since runoff occurs, bacteria and nutrients located in the off-stream watering area could enter the stream via surface runoff. The reduced bacterial and nutrient direct stream inputs (75%) minus the amount entering the stream from surface runoff are compared to the original direct stream inputs when no off-stream watering area is available. To estimate the bacteria, nitrogen, and phosphorus entering runoff during the rain event, the amount accumulated in the off-stream watering area since the last rainfall is calculated for Enterprise No. 2. Since the last rain event is assumed to be thirty days ago, the accumulated nitrogen and phosphorus available for runoff is 0.32 and 0.13 pounds (150 and 59 grams) respectively. The accumulated bacteria is estimated using die-off rates calculated from Moore et al.'s (1989) equation. The average daily temperature and soil pH used were 60^{o}F (15.6^{o}C) and pH 7. This gives a fecal coliform die-off rate of 0.047 days^{-1}. It is assumed the fecal streptococcus die-off rate is similar and rates do not vary by animal types.

The off-stream watering area was placed 50 feet (15 meters) from the stream with a 3% slope for the pastured area between. Considering antecedent soil moisture and summer conditions, the bacteria filtered were assumed to be 99.7% of the quantity available for runoff. This percentage was based on Larsen et al.'s (1993) study. If the off-stream watering area is 25 by 25 feet (7.6 by 7.6 meters) and using the quantities available for runoff, the nitrogen and phosphorus applied over the thirty days are 22 and 9 pounds per acre (25 and 10 kg per hectare). The percentages filtered from runoff are assumed to be 100% since these are equivalent to low fertilization rates and occur over 30 days (based on Moore and Gamroth, (1989). Even if the rain event saturates the soil below the root zone, the nitrogen filtered from entering groundwater supplies is assumed to be 100%.

The volume of runoff and number of bacteria leaving the off-stream watering area were used to calculate bacteria per ml reaching the stream. Using 0.1 inch (0.25 cm) runoff and the 625 square foot (58.1 square meters) watering area, the fecal coliform and fecal streptococcus concentrations calculated to enter the stream from the off-stream watering area are 44 and 250 per ml respectively. Appendix E shows additional information and calculations regarding bacteria accumulations and volume of water runoff from the off-stream watering area.

Table 7.2 shows the 30 day accumulations of bacteria, nitrogen, and phosphorus entering the stream from Enterprise No. 2, with and without an off-stream watering area, for this weather scenario. The effectiveness of the off-stream watering area in reducing bacteria and nutrients from entering the stream is 73 and 75% respectively, while the effectiveness in reducing nitrogen leaching to groundwater is zero.

For Enterprise No. 1, the accumulated nitrogen and phosphorus in the off-stream watering area over 30 days is 0.22 and 0.046 pounds (100 and 21 grams) respectively. This assumed 12 defecations in the area over 30 days Assuming the same size off-stream watering area, this is equivalent to 15 pounds (17 kg) nitrogen and 3.2 pounds (3.6 kg) phosphorus per acre (hectare). The bacteria accumulated in the off-stream watering area for 30 days was calculated and is shown in Appendix E. The off-stream watering area is 175 feet (53 meters) from the stream with a 3% slope. Considering the distance from the stream, antecedent soil moisture and summer conditions, and nutrients and bacteria available for runoff, the quantity of bacteria, nitrogen, and phosphorus filtered from entering the stream is assumed to be 99.8, 100, and 100%. Even if the rain event saturates the soil below the root zone, there is not enough nitrogen to be a threat to the groundwater supply.

Table 7.2 illustrates the 30 day accumulations of bacteria, nitrogen, and phosphorus entering the stream from Enterprise No. 1, with and without an off-stream watering area, for this weather scenario. Based on the watering area and 0.10 inch (0.25 cm) runoff depth, the fecal coliform and fecal streptococcus concentrations calculated to enter the stream from the off-stream watering area are 1.0 and 506 per ml respectively. The effectiveness of the off-stream watering area in reducing bacteria and nutrients from entering the stream is 80%, while percent effectiveness for nitrogen leaching to groundwater is still zero.

The previous analyses used a summer day with 1.30 inches of rain and summer soil conditions. Chapter 6 illustrated that the possibility of this event occurring from April to September in the Dairy-McKay H.U.A. is very small.

Table 7.2. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) entering the stream from Enterprises No. 1 and 2 for a summer day with 1.30 inches (3.30 cm) rain.

30 Day Weather Scenarios	No Off-Stream Watering Area	Off-Stream Watering Area
Summer 1.30 inch Rain Event every 30 days	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)
Enterprise No. 1	0.32, 160, 150, 26	0.064, 32, 31, 5.4
Enterprise No. 2	9.8, 55, 240, 77	2.6, 15, 59, 20

Winter Weather Scenarios

The main differences between the summer scenarios and the three winter scenarios are the amount of nitrogen, phosphorus, and bacteria not filtered from runoff and the nitrogen leaching to groundwater. The same direct stream inputs still occur based on the presence or absence of an off-stream watering area.

The first scenario considered is a winter day with no rain and less than saturated antecedent soil moisture conditions (e.g. no rain for the past three days). Since there is no runoff and the soil conditions are less than saturated, this scenario does not differ from the summer dry weather scenario (same percent effectiveness). If a rain event occurred one day previously, there would still be no runoff. The only change would be the nitrogen assumed to leach to groundwater. If the soil is saturated, 10% of the unvolatilized nitrogen defecated that day is assumed to be leached. This would be .0014 pounds (0.64 grams) nitrogen from Enterprise No. 2 and 0.0018 pounds (0.82 grams) nitrogen from Enterprise No. 1.

The second scenario considered is a winter day with 0.61 inch (1.5 cm) rain and less than saturated antecedent soil moisture conditions (no rain events in the previous three days). Since 0.10 inch (0.25 cm) runoff occurs, the accumulated bacteria and nutrients since the previous rain event are calculated. The procedure is basically the same as previously discussed, but the bacteria and nutrients enter the stream on a four day cycle and the bacteria die-off rates differ when using the Moore et al. (1989) method. The calculated winter bacterial die-off rate is 0.023 $days^{-1}$ using $40^{o}F$ ($4.4^{o}C$) for the average daily temperature. The procedure and calculations for bacteria entering the stream are shown in Appendix E.

The antecedent soil moisture conditions and the rain event are assumed to reduce the bacteria filtration capacity of the buffer strips to 98% for both enterprises. Since the soil had three days to dry, the soil maintains most of its ability to hold and filter bacteria. The quantities of nitrogen and phosphorus not filtered from surface runoff are assumed to be 10% of the amount defecated and not volatilized in the off-stream watering area since the last rainfall. This assumes that nutrients remaining in the area following the rainfall are not available to enter runoff for the next rainfall of the same size.

Table 7.3 shows the 30 day accumulations of bacteria, nitrogen, and phosphorus reaching the stream from Enterprises No. 1 and 2, with and without an off-stream watering area for this weather scenario. The fecal coliform and fecal streptococcus concentrations calculated to reach the stream from the off-stream watering area are 110 and 620 per ml., respectively, for Enterprise No. 2 and 4.1 and 210 per ml., respectively, for Enterprise No. 1. The effectiveness of the off-stream watering areas in Enterprises No. 1 and 2 in reducing bacteria from entering the stream are 78 and 72% respectively. The effectiveness in reducing nitrogen and phosphorus are 74% for Enterprise No. 1 and 69% (nitrogen) and 68% (phosphorus) for Enterprise No. 2.

Since the rainfall would saturate the soil, some nitrogen is assumed to leach towards groundwater. Due to the prior three days of no rain, only 10% of the unvolatilized nitrogen defecated the day of rainfall is assumed to be leached. This would be 0.0014 pounds (0.64 grams) nitrogen from Enterprise No. 1 and 0.0018 pounds (0.82 grams) nitrogen from Enterprise No. 2 leaching on the days of rain. The effectiveness of the off-stream watering areas in reducing nitrogen leaching to groundwater are -10% on the days of rain for both enterprises.

Table 7.3. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) entering the stream from Enterprises No. 1 and 2 for a winter day with 0.61 inch (1.5 cm) rain every four days.

30 Day Weather Scenarios	No Off-Stream Watering Area	Off-Stream Watering Area
Winter 0.61 inch Rain Event every 4 days	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)
Enterprise No. 1	0.32, 160, 150, 26	0.069, 35, 47, 8.9
Enterprise No. 2	9.8, 55, 240, 77	2.6, 15, 78, 27

If the same winter rain event occurred everyday, the bacteria and nutrients filtered from surface runoff and leachate moving to groundwater would decrease. The bacteria filtered from runoff from both enterprises is assumed to be 75% of the amount accumulated in the off-stream watering area since the previous rain. The percentages of nitrogen and phosphorus not filtered from runoff would be 20% of the defecated nitrogen (not volatilized) and phosphorus on the day they were defecated. These percentages of filtered bacteria and nutrients decreased due to rainfall occurring everyday on the fresh defecations, no drying period for the soil, and the possibility of the bacteria and nutrients settling or being trapped in the vegetation.

The 30 day accumulations of bacteria , nitrogen, and phosphorus entering the stream from these enterprises, with and without off-stream watering areas, for this weather scenario are shown in Table 7.4 (bacterial analysis in Appendix E). The fecal coliform and fecal streptococcus concentrations calculated to enter the stream from the off-stream watering areas are 405.3 and 2,291 per ml., respectively, for Enterprise No. 2 and 14.53 and 7,266 per ml., respectively, for Enterprise No. 1. The effectiveness of the off-stream watering areas in reducing bacterial inputs to the stream are 55% for Enterprise No. 2 and 60% for Enterprise No. 1. The effectiveness in reducing nitrogen and phosphorus inputs to the stream are 63 and 60%, respectively, for Enterprise No. 2 and 67 and 64%, respectively, for Enterprise No. 1. The nitrogen assumed to leach to groundwater is 10% of that defecated and not volatilized in the off-stream watering areas for both enterprises. These quantities of nitrogen were mentioned previously for both enterprises. The effectiveness of off-stream watering areas in reducing nitrogen leaching to groundwater is -10%.

Table 7.4. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) entering the stream from Enterprises No. 1 and 2 for a winter day with 0.61 inch (1.5 cm) rain every day.

30 Day Weather Scenarios	No Off-Stream Watering Area	Off-Stream Watering Area
Winter 0.61 inch Rain Event every day	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)
Enterprise No. 1	0.32, 160, 150, 26	0.13, 64, 64, 12
Enterprise No. 2	9.8, 55, 240, 77	4.4, 25, 98, 35

The last scenario considered is a winter day with 0.89 inch (2.3 cm) rain causing 0.25 inch (0.64 cm) runoff. First, the less than saturated antecedent soil moisture condition, no rain for the previous three days, will be considered for Enterprises 1 and 2.

Bacterial filtration from surface runoff is assumed to be 90% of the amount defecated in the off-stream watering areas since the previous rain for Enterprises 1 and 2. The nitrogen and phosphorus not filtered from surface runoff is 20% of the amount defecated and not volatilized in the off-stream watering areas. These percentages were chosen due to the depth of runoff and antecedent soil moisture conditions. Table 7.5

shows the 30 day accumulations of bacteria and nutrients reaching the stream from Enterprises No. 2 and 1 for this weather scenario.

Table 7.5. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) entering the stream from Enterprises No. 1 and 2 for a winter day with 0.89 inch (2.3 cm) rain every four days.

30 Day Weather Scenarios	No Off-Stream Watering Area	Off-Stream Watering Area
Winter 0.89 inch Rain Event every 4 days	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)
Enterprise No. 1	0.32, 160, 150, 26	0.089, 44, 64, 12
Enterprise No. 2	9.8, 55, 240, 77	3.3, 18, 98, 35

The fecal coliform and fecal streptococcus concentrations calculated to reach the stream from the off-stream watering areas are calculated to be 220 and 1,240 per ml., respectively, for Enterprise No.2 and 8.3 and 4,100 ml., respectively, for Enterprise No. 1 (bacterial analysis in Appendix E). The effectiveness of the off-stream watering areas in reducing bacteria from reaching the stream is 67 and 72% for Enterprises 2 and 1, respectively. The effectiveness in reducing nitrogen and phosphorus from reaching the stream is 63 and 60%, respectively, for Enterprise No. 2 and 67 and 64%, respectively, for Enterprise No. 1. The nitrogen assumed to leach to groundwater for both Enterprises is 10% of the amount defecated and not volatilized on the day of rainfall. These amounts have been mentioned previously for both operations. The effectiveness in reducing in reducing nitrogen from leaching to groundwater for both enterprises is -10% on the days of rain.

If the same winter rain event occurred every day, the bacteria and nutrients filtered from surface runoff and leachate moving to groundwater would decrease. Bacterial filtration from surface runoff is assumed to be 50% of the amount defecated due to the depth of runoff and no soil drying period. The nitrogen and phosphorus not filtered from surface runoff is assumed to increase to 30% of the unvolatilized nutrients defecated daily in the off-stream watering area. The fecal coliform and fecal streptococcus concentrations calculated to reach the stream from the off-stream watering area are 320 and 1,800 per ml., respectively, for Enterprise No. 2 and 12 and 5,800 per ml., respectively, for Enterprise No. 1. Table 7.6 shows the 30 day accumulations of bacteria and nutrients reaching the stream from both enterprises, with and without off-stream watering areas, for this weather scenario.

Table 7.6. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) entering the stream from Enterprises No. 1 and 2 for a winter day with 0.89 inch (2.3 cm) rain every day.

30 Day Weather Scenarios	No Off-Stream Watering Area	Off-Stream Watering Area
Winter 0.89 inch Rain Event every day	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)	Amount Reaching Stream FC & FS ($x10^9$), N & P (g)
Enterprise No. 1	0.32, 160, 150, 26	0.19, 96, 80, 16
Enterprise No. 2	9.8, 55, 240, 77	6.2, 35, 120, 43

The effectiveness of off-stream watering areas in reducing bacteria from entering the stream is 37 and 40% for Enterprises No. 2 and 1, respectively. The effectiveness in reducing nitrogen and phosphorus from reaching the stream is 57 and 53%, respectively, for Enterprise No. 2 and 61 and 56%, respectively, for Enterprise No. 1. The nitrogen assumed to leach to groundwater from both enterprises is assumed to be 10% of the amount defecated and unvolatilized in the off-stream watering areas. This quantity has already been given. The effectiveness in reducing nitrogen from leaching to groundwater is -10% for both enterprises.

7.5 Covered Manure Storages

Covered storage facilities with impermeable floors are designed to keep rain off manure piles and prevent nutrients and bacteria from entering surface runoff or leaching to groundwater. For the Tualatin River Basin, 150 to 180 day storage capacity allows the manure to be transported off-site or spread on fields when weather conditions cause minimal runoff. The alternative practice is piling collected manure and leaving it uncovered until weather conditions permit transport off-site or land spreading. SCAEs collect manure from any animals raised inside, on dry lots, and in winter holding areas, basically, any area used repeatedly during the winter or summer where manure accumulation is a nuisance to the objectives of the operation. These areas are usually unvegetated and resemble feedlot properties in the winter. Whether manure is piled in the open or in storage, the collection area and process is the same. Therefore, the change in practice from uncovered piles to stored piles is assumed to not change the nutrients and bacteria lost from the collection area.

Covered manure storage facilities with impermeable flooring are assumed to be 100% effective in reducing bacteria and nutrients entering surface water or leaching to groundwater. Covered manure piles without flooring may have some nitrogen leaching depending on the wetness of the manure when piled. In addition, these piles may allow nutrients and bacteria to enter surface water runoff depending on their location and surrounding surface water drainage. No nutrients and bacteria will enter surface runoff if the pile is on higher ground than neighboring areas or water diversions are used.

Since covered manure storage facilities are 100% effective in reducing water quality impacts, this analysis estimates the change in water quality impacts from implementing from implementing the BMP by comparing bacteria and nutrient loss to surface and groundwater from a covered versus an uncovered manure pile. The same general procedure for estimating pollution reductions from off-stream watering areas is used for covered manure storages.

Enterprise No. 1 implemented a covered compost facility for storing collected manure from two horses when they are housed in the barn. Enterprise No. 3 implemented a covered manure storage facility for collected manure from beef cows. Since the location of these enterprises' manure piles were so far from the stream and separated by healthy pasture, any nutrients and bacteria entering surface runoff are assumed to be filtered before reaching the stream. However, both piles show potential for nitrogen leaching to groundwater. Both of these enterprises will only be analyzed for their impact to groundwater quality.

This analysis will use summer and winter scenarios that yield the same runoff and antecedent soil moisture conditions used in the off-stream watering area analysis. Areas where manure is collected and piled for these small farm operations would produce similar curve numbers and estimated frequency of runoff as row crops. The amount of rainfall required to produce runoff from row crops are calculated in Chapter 6. A summer day with 0.83 inch (2.1 cm) rain is estimated to produce 0.10 inch (0.25 cm) runoff. A winter day with 0.61 inch (1.5 cm) rain is estimated to produce 0.10 inch runoff, while a winter day with 0.89 inch (2.3 cm) rain is estimated to produce 0.25 inch (0.64 cm) runoff.

Description of Manure Piles

To predict the nutrients and bacteria available for runoff from a manure pile, the quantity and frequency they are added to the pile is estimated. Enterprises No. 1, 2, and 3 mentioned in Chapter 3 collect and pile manure twice weekly, while Enterprise No. 4 collects three times weekly. For Enterprises 2 and 3, it is assumed that 50% of the defecated manure in the collection areas will be collected and piled in the summer and 90% in the winter. Enterprises No. 1 and 4 are assumed to collect 90 and 80%, respectively, of the defecated manure year round. An additional 20% nitrogen loss through volatilization is assumed to occur after defecation year round.

Enterprise No. 1 collects the manure defecated from two horses when they are housed at night. They are usually housed 12 to 14 hours yielding two total defecations a night for collection. Since manure is collected twice weekly, the nitrogen and phosphorus added to the pile every four day collection period is 0.13 and 0.028 pounds (59 and 13 grams) respectively. The amount added every three day collection period is 0.097 pounds (44 grams) nitrogen and 0.021 pounds (9.5 grams) phosphorus.

Enterprise No. 2 collects the defecated manure from two calves averaging 400 pounds (180 kg), one boar, six sows, five growing pigs, and 30 turkeys during the summer period. In the winter, the defecated manure is collected from two cows averaging 600 pounds (270 kg), two calves averaging 400 pounds, one boar, and six sows. The amount of nitrogen and phosphorus added to the pile every four days during the summer is 2.8 and 0.38 pounds (1.3 and 0.17 kg) respectively. The amount added every three days is 2.1 pounds (0.95 kg) nitrogen and 0.28 pounds (0.13 kg) phosphorus. In the winter, this is increased to 3.3 pounds (1.5 kg) nitrogen and 1.3 pounds (0.59 kg) phosphorus added every four days and 2.4 pounds (1.1 kg) nitrogen and 1.0 pounds (0.45 kg) phosphorus added every three days.

Enterprise No. 3 collects the defecated manure from one cow averaging 1000 pounds (450 kg) and one calf averaging 500 pounds (230 kg) in the summer. In the winter, defecated manure is collected from 6 cows averaging 1000 pounds and 2 cows averaging 500 pounds. The amount of nitrogen and phosphorus applied to the manure pile every four days in the summer is 0.82 and 0.33 pounds (370 and 150 grams) respectively. The amount added every three days is 0.61 pounds (280 grams) nitrogen and 0.25 pounds (110 grams) phosphorus. This is increased in the winter to 6.9 pounds (3.1 kg) nitrogen and 2.8 pounds (1.3 kg) phosphorus applied every four days and 5.1 pounds (2.3 kg) nitrogen and 2.1 pounds (0.95 kg) phosphorus applied every three days.

Enterprise No. 4 collects defecated manure from twelve horses averaging 1000 pounds in the summer and fifteen horses averaging 1000 pounds in the winter. The amount of nitrogen and phosphorus applied to the manure pile every three days in the summer is 6.2 and 1.3 pounds (2.8 and 0.59 kg). The amount applied every two days is 4.2 pounds (1.9 kg) nitrogen and 0.88 pounds (0.40 kg) phosphorus. In the winter, this is increased to 8.6 pounds (3.9 kg) nitrogen and 1.7 pounds (0.77 kg) phosphorus applied every three days and 5.8 pounds (2.6 kg) nitrogen and 1.1 pounds (0.50 kg) phosphorus applied every two days.

Bacteria and Nutrient Release Rates

Bacteria entering surface water runoff from uncovered manure piles are estimated using Thelin and Gifford's (1983) bacteria release rates. These rates vary with age of the manure when rainfall occurs. Only the manure applied to the top of the pile since the last rainfall is assumed to release bacteria. For the summer scenarios, the average age of the manure is assumed to be 15 days old. For the winter scenarios of rain every four days and every day, the age of the manure applied will depend on the collection rate and days since rainfall. The age of the manure collected twice weekly will average three days old for rain every four days, and average two days old for rain every day. The age of the manure collected three times weekly will average two days old for rain every four days, and average one day old for rain every day. However, average age must be greater than or equal to two in the release rate equation.

The percentages of nitrogen and phosphorus released from the manure pile and entering surface runoff are assumed to range from 10 to 20 for different weather scenarios. For the summer scenario of 0.83 inch (2.1 cm) rain, 10% of the nitrogen and phosphorus applied to the manure pile in the last four days is assumed to be available for runoff. The winter scenario of a day with 0.61 inch (1.56 cm) rain, and no rain for the last three days, yields 10% of the nitrogen and phosphorus applied to the manure pile since the last rainfall is assumed to be available for runoff. The winter scenarios of 0.61 inch (1.5 cm) rain, with a previous day of rain, and 0.89 inch (2.3 cm) rain, with no rain in three days, is assumed to yield 15% of the nutrients applied to the pile since the previous rain available for runoff. For the days with rain occurring everyday, nutrients are considered to enter the runoff only on the day they are applied to the pile. The percentage of nutrients entering runoff is increased to 20% under the winter scenario of a 0.89 inch rain with rain the previous day.

There are three conditions where a percentage of the nitrogen applied to the manure pile since the previous rain event is assumed to leach to groundwater. The winter days of 0.61 inch (1.5 cm.) rain, with rain the previous day, and 0.89 inch (2.3 cm.) rain, with no rain for the last three days, cause 5% of the unvolatilized nitrogen to leach. This percentage increases to 10% for the winter day of 0.89 inch rain with rain the previous day.

The following sections analyze uncovered manure piles in four SCAEs for bacteria, nitrogen, and phosphorus loads reaching the stream or groundwater for summer and winter weather scenarios. Since the enterprises collect and pile their manure on a weekly schedule, the scenarios are analyzed for one week. Bacteria concentrations leaving the manure pile are computed using the average age of the manure on top of the pile when rainfall occurs. When rain occurs everyday, bacteria are assumed to enter runoff only on the day manure is added to the pile. Therefore, to calculate seven day average concentrations when rain occurs everyday, the original bacterial concentration leaving the pile must be multiplied by two and divided by seven for operations collecting manure twice weekly. For operations collecting manure three times weekly, the original bacterial concentration is multiplied by three and divided by seven. The seven day accumulations of nitrogen and phosphorus in the runoff are calculated using percentages of the total manure collected weekly. To compare with the off-stream watering area results, these weekly values are converted to 30 day accumulations. Bacteria concentrations are converted to numbers of bacteria using a 25 by 25 foot (7.6 by 7.6 meter) area for the manure pile, depth of rainfall, and number of days rain occurred in the 30 day period. Nutrient loads are converted by multiplying weekly values by 30 and dividing by 7.

Summer Weather Scenarios

For a summer day with no rain and dry antecedent soil moisture conditions, no rain for the past 30 days, nutrients and bacteria would not enter surface or groundwater supplies from uncovered manure piles. Therefore, implementing covered manure storages would not reduce any of the enterprises' water quality impacts.

For a summer day of 0.83 inch (2.1 cm) rain and same soil moisture conditions, nutrients and bacteria would be released from the uncovered manure pile and enter surface runoff, but no nitrogen would leach to groundwater. Bacteria and nutrients from all enterprises are assumed to be filtered from the runoff except No. 2. Enterprise No. 2 has the most ineffective buffer between the manure pile and the stream. This operation's uncovered manure pile is assumed to yield 10% of the bacteria and nutrients in surface runoff to the stream. The 30 day accumulations of bacteria, nitrogen, and phosphorus reaching the stream and groundwater are shown in Table 7.7. No reduction in groundwater quality impact would be gained from implementing covered manure storages in any of the enterprises.

Table 7.7. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) in the stream and nitrogen in groundwater from an uncovered manure pile in Enterprises No. 1,2,3, and 4 for a summer day with 0.83 inch (2.1 cm) rain.

30 Day Weather Scenarios	Enterprises	Uncovered Manure Pile: Stream FC/FS (x 10^6), N & P (g)	Uncovered Manure Pile: Groundwater N (g)
Summer	#1	0, 0, 0	0
0.83 inch Rain Event	#2	2.3, 490, 70	0
every 30 days	#3	0, 0, 0	0
	#4	0, 0, 0	0

Winter Weather Scenarios

For the winter days of no rain, no surface runoff occurs and uncovered manure piles are assumed not to leach nitrogen to groundwater. Implementing covered manure storages would not reduce the stream or groundwater quality impacts from any of the four enterprises. The winter day of 0.61 inch (1.5 cm) rain, with no rain in three days, would cause surface runoff. The bacteria from uncovered manure piles filtered from runoff before reaching the stream are assumed to be 75% for Enterprise No. 2 and 100% from the other three enterprises. The nutrients filtered from runoff are 75% for Enterprise No. 2, 95% for No. 4, and 100% for No. 1 and 3. No nitrogen is assumed to leach into groundwater from uncovered manure piles in any of the four enterprises. The 30 day accumulations of bacteria, nitrogen, and phosphorus reaching the stream and groundwater from uncovered manure piles in these enterprises are illustrated in Table 7.8. Implementing covered manure storages would eliminate the 25% of bacteria and nutrients in runoff reaching the stream for Enterprise No. 2, and eliminate the 5% of the nutrients in runoff reaching the stream for Enterprise No. 4.

Table 7.8. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) in the stream and nitrogen in groundwater from an uncovered manure pile in Enterprises No. 1,2,3, and 4 for a winter day with 0.61 inch (1.5 cm) rain.

		Uncovered Manure Pile	
30 Day Weather Scenarios	Enterprises	Stream FC/FS (x 10^9), N & P (g)	Groundwater N (g)
Winter	#1	0, 0, 0	0
0.61 inch Rain Event	#2	6.3, 270, 110	0
twice every 7 days	#3	0, 0, 0	0
	#4	0, 190, 37	0
Winter	#1	0, 0, 0	110
0.61 inch Rain Event	#2	46, 840, 350	560
every day	#3	0, 0, 0	1200
	#4	14, 1200, 230	2000

For the same winter day of rain, but with saturated antecedent soil moisture conditions (rain the previous day), surface runoff would increase and nitrogen leaching towards groundwater would occur for all enterprises. The bacteria from uncovered manure piles filtered from runoff are assumed to decrease to 50 and 90% for Enterprises No. 2 and 4, respectively. However, the nutrients filtered from runoff are assumed to decrease to 50 and 80% for No. 2 and 4. The quantity of nitrogen from uncovered manure piles leaching towards groundwater for each operation is assumed to be 5% of the nitrogen added to the pile since the last day of rain. Table 7.8 shows 30 day accumulations of bacteria, nitrogen, and phosphorus reaching the stream and groundwater from uncovered manure piles in each enterprise.

The last scenario considered is a winter day of 0.89 inch (2.3 cm) rain causing 0.25 inch (0.64 cm) surface runoff. This rain event following three days of no rain will be analyzed first. The bacteria and nitrogen, from uncovered manure piles, filtered from runoff are assumed to be 60% for Enterprise No. 2, and 95 and 85%, respectively, for Enterprise No. 4. All operations are assumed to have 5% of nitrogen added to uncovered manure piles since the previous day of rain leach to groundwater. Table 7.9 shows the 30 day accumulations of bacteria and nutrients reaching the stream and groundwater from uncovered manure piles in the four enterprises.

Table 7.9. 30 Day accumulations of fecal coliforms (FC), fecal streptococci (FS), nitrogen (N), and phosphorus (P) in the stream and nitrogen in groundwater from an uncovered manure pile in Enterprises No. 1,2,3, and 4 for a winter day with 0.89 inch (2.3 cm) rain.

		Uncovered Manure Pile	
30 Day Weather Scenarios	Enterprises	Stream FC/FS (x 10^{11}), N & P (g)	Groundwater N (g)
Winter	#1	0, 0, 0	11
0.89 inch Rain Event	#2	3.7, 660, 270	560
twice every 7 days	#3	0, 0, 0	1200
	#4	1.2, 870, 170	2000
Winter	#1	0, 0, 0	21
0.89 inch Rain Event	#2	15, 1300, 540	1100
every day	#3	0, 0, 0	2300
	#4	5.5, 2300, 450	3900

For the same winter day with rain the previous day instead of four days ago, less bacteria and nutrients would be filtered from runoff and leachate moving to groundwater. The bacteria and nutrients released from uncovered manure piles and filtered from runoff decrease to 40% for Enterprise No.2 and 85 and70%, respectively, for Enterprise No. 4. All enterprises are assumed to contribute 10% of the nitrogen, added to uncovered manure piles since the previous day of rain, to groundwater. Table 7.9 shows the 30 day accumulations of bacteria and nutrients entering the stream and groundwater from uncovered manure piles in these enterprises for this weather scenario. Implementing covered manure storages on all four enterprises for this winter scenario would have the greatest reduction in water quality impacts.

7.6 Total Basin Reductions

Implementing off-stream watering areas and covered manure storages in SCAEs are analyzed for potential reductions in bacteria, nitrogen, and phosphorus loads to streams and groundwater in the Tualatin River Basin. Miner et al. (1993) conducted a telephone survey of Washington County, and stated that the majority of enterprises owning animals are managing fewer than 20 and were considered SCAEs. Fifty-nine out of seventy-eight landowners provided information regarding manure handling techniques, with 88% of these being SCAEs (52 of 59). The SCAEs have 5.1% of their manure piles covered and 44% uncovered, while the remaining percentages have no manure handling practices. Thirty-seven percent (29 of 78) of all animal operations have perennial streams on their land with 55% of these allowing animal access. Nineteen percent (15 of 78) of all animal operations have an intermittent stream with 32% of these allowing animal access. The remaining 34 animal operations (44%) have no stream on their property.

The survey is assumed to adequately represent the distribution of SCAEs in the Tualatin River Basin. If the number of SCAEs are assumed to be 88% of the total animal operations (69 of 78), then 56% of these (39) would have a perennial or intermittent stream. Furthermore, 50% of the operations with streams (19), 28% of SCAEs, allow animal access.

The following analysis assumes that implementing off-stream watering areas and covered manure storages in SCAEs would have the same water quality improvements as analyzed for Enterprise No. 2. In addition, all 44% of the SCAEs having uncovered manure piles in the Tualatin River Basin are assumed to be next to a stream. The assumption of similarity with enterprise number two causes the water quality impact assessments to approximate the maximum reduction percentage. This is due to the manure pile being close to the stream with minimal vegetated filter.

During the summer rain, summer no rain, and winter no rain scenarios, implementing off-stream watering areas in SCAEs could reduce bacteria and nutrients from reaching the stream by 75%. This would be implemented on 28% of the SCAEs in the basin for a 21% total improvement of their impact on stream water quality. No added impact to groundwater quality would occur.

For the winter 0.61 inch (1.5 cm) rain event occurring every four days, implementing off-stream watering areas could reduce bacteria and nutrients from reaching the stream by 72 and 69%, respectively. This yields a 20 and 19% total improvement for all SCAEs' impact on bacterial and nutrient stream water quality. The added impact to original groundwater quality from nitrogen leaching is minimal.

If the winter 0.61 inch rain event occurred following a previous day of rain, implementing off-stream watering areas could reduce bacteria and nutrients form reaching the stream by 55 and 63%, respectively. This yields a 15 and 18% total improvement for all SCAEs bacterial and nutrient impact on stream water quality, respectively. The nitrogen leaching to groundwater from the off-stream watering areas is assumed to be increased by 10% of the nitrogen defecated in these areas. The total additional nitrogen leaching to groundwater would be 0.7% of the total unvolatilized nitrogen originally defecated in the stream from all SCAEs.

For the winter scenario of a day with 0.89 inch (2.3 cm) rain occurring after four days of no rain, implementing off-stream watering areas could reduce bacteria and nutrients entering the stream by 67 and 63%, respectively. Therefore, the total improvement of all SCAEs in reducing bacteria and nutrient loads in streams would be 19 and 18%, respectively. The additional impact on groundwater quality due to nitrogen leaching would be minimal.

For the same winter day of rain following rain the previous day, off-stream watering areas could reduce bacteria and nitrogen from entering the stream by 37 and 57%. The total improvement of all SCAEs from bacteria and nutrients entering the stream would be 10 and 16%, respectively. The additional nitrogen leaching to groundwater is assumed to be 2.5% of the unvolatilized nitrogen defecated in the stream without an off-stream watering area. The total additional nitrogen leaching to groundwater would be 0.7% of the unvolatilized nitrogen defecated in the stream from all operations prior to implementing the practice.

Implementing covered manure storages with impermeable floors in place of uncovered manure piles eliminate bacteria and nitrogen entering the stream and groundwater from uncovered manure piles, but the amount of bacteria and nitrogen eliminated changes with the weather conditions. Uncovered manure piles do not affect water quality during summer and winter no rain scenarios. If the uncovered manure pile is far enough away from the stream, then covering it will only prevent groundwater quality impacts. Nitrogen leaching to groundwater from uncovered manure piles are assumed to occur during winter days of 0.61 inch rain following a previous day of rain, and a day of 0.89 inch rain following four days with no rain or rain the previous day.

For a summer day with 0.83 inch rain, 10% of bacteria and nutrients, in the runoff from the uncovered manure pile, enter the stream. This yields 4% of bacteria and nutrients in runoff, from uncovered manure piles, entering streams for all SCAEs. For a winter day of 0.61 inch rain with no rain in three days, 25% of bacteria and nutrients in the runoff, from an uncovered manure pile, enter the stream. Therefore, uncovered manure piles in all SCAEs would cause 11% of bacteria and nutrients in runoff to enter the streams.

For the same winter day of rain following rain the previous day, 50% of bacteria and nutrients in runoff from manure piles are assumed to enter the stream. This would be 22% of bacteria and nutrients in runoff from all uncovered manure piles to enter the stream for all SCAEs. An additional 5% of the nitrogen, added to an uncovered manure pile since the previous rain, is assumed to leach to groundwater. This would be 3% of the nitrogen in uncovered manure piles to leach to groundwater for all SCAEs.

For a winter day of 0.89 inch rain occurring after three days of no rain, 40% of bacteria and nutrients in runoff, from an uncovered manure pile, are assumed to enter the stream. In addition, 5% of nitrogen added to an uncovered manure pile since the previous rain is assumed to leach to groundwater. This would be 18% of the bacteria and nutrients in the runoff, from uncovered manure piles, reaching the stream, while 2% of the nitrogen in uncovered manure piles would leach to groundwater for all SCAEs.

For this same winter day of rain following a previous day of rain, 60% of bacteria and nutrients in runoff, from uncovered manure piles, enter the stream. This would yield 26% of bacteria and nutrients in runoff, from uncovered manure piles, entering the stream for all SCAEs. In addition, 10% of nitrogen added to uncovered manure piles since the previous rain could leach to groundwater. This would yield 4% of nitrogen in uncovered manure piles to leach to groundwater for all SCAEs.

7.7 Conclusion

Implementing off-stream watering areas with animal access to streams and covered manure storages reduce the bacteria, nitrogen, and phosphorus loads entering the stream and groundwater from SCAEs, but their effectiveness varies with different weather conditions. Estimating effectiveness of off-stream watering areas is based on the percent reduction of the originally defecated bacteria and nutrients in the stream. Off-stream watering areas are most effective during days with no rain. The effectiveness in reducing bacterial and nutrient loads from entering the stream ranged from 80% in dry weather to 37% in winter days of rain following previous days of rain. Off-stream watering areas may have small amounts of nitrogen leaching to groundwater during saturated soil and winter conditions.

Alternatively, covered manure storage facilities that replace uncovered manure piles are 100% effective regardless of the weather. This improvement is based on reducing the bacteria and nutrients from an uncovered manure pile that reach the stream or leach to groundwater. The greatest reductions are for winter days of continuous rain, but provide no reductions for days with no rain. Enterprises that have uncovered manure piles farther than 250 feet (76 meters) from a stream only impact the nitrogen leaching to groundwater.

Miner et al. (1993) estimated that a majority of all landowners raising animals in the Tualatin River Basin are SCAEs, with 28% of the SCAEs allowing animal access to streams and 44% having uncovered manure piles. Therefore, implementing these BMPs could substantially improve SCAEs' impact on the basin's water quality for different weather conditions.

CHAPTER 8

ECONOMIC ANALYSIS OF IMPLEMENTED BEST MANAGEMENT PRACTICES FOR FOUR SMALL COMMERCIAL AND NON-COMMERCIAL ANIMAL ENTERPRISES

8.1 Abstract

Implementing BMPs initiate implementation costs, as well as changes in annual revenue and costs associated with managing the new practice. Partial budget economic analyses are conducted for the four SCAEs described in Chapter 3. The analyses review monetary changes in annual revenue and costs associated with implementing covered manure storages, covered compost facilities, and off-stream watering devices. All four enterprises have negative changes in annual returns to management following the implementation of each BMP. The changes in annual returns range from -324 to -704 dollars. Even though Enterprise No. 1 is the smallest enterprise, it has the second most negative change in annual return to management. This is mainly due to one hour of increased labor per week. Enterprise No. 4 has the most negative change in annual return to management. This is attributed to the largest depreciation, repairs, and alternative investment costs of all the enterprises. The partial budget analyses did not consider the enterprises' personal and economic objectives. All enterprises received subsidies to implement the practices, but these subsidies were not included in the analyses.

8.2 Introduction

Presently in Oregon, the Oregon Department of Agriculture educates SCAEs in installing and maintaining BMPs to control their pollution problems. These practices are voluntarily implemented with subsidies available to curtail certain implementation costs. Four enterprises, their implemented BMPs, and associated implementation costs are described in Chapter 3.

Once an animal enterprise implements a BMP, annual costs and revenue transpire that may not meet the owner's objective. Owners calculate expected changes in annual revenue and costs of converting the operation and decide if their objectives will be reached. Partial budget analyses are commonly used by farm business managers to examine expected changes in annual revenue and costs associated with implementing BMPs.

This study's objective is to conduct partial budget analyses to determine changes in annual revenue and costs from implementing BMPs for the four SCAEs described in Chapter 3. The BMPs analyzed are off-stream watering areas, covered manure storage facilities, and covered compost facilities. This paper may serve as a general guide to government agencies and SCAEs making decisions on implementing BMPs. Each enterprises' personal and economic objectives varied and are not considered in these analyses.

8.3 Partial Budget Analyses

The partial budget analysis design is based on Castle et al. (1987). The analyses use each enterprises' estimated change in annual revenue and costs and standard cost equations described in Castle et al. (1987). The standard cost equations use the implementation costs and estimate annual labor costs, depreciation, repair costs, and alternative investment (interest) costs. All implementation costs of the BMPs for the four enterprises are described in Chapter 3. Note that these costs and the following analyses do not consider the government subsidies provided for the SCAEs.

Annual labor costs are calculated from standard wage rates plus overhead costs. Standard wage rates for the area range from five to six dollars per hour plus 30% payroll overhead. The total wage rate used for all enterprises is seven dollars per hour. When calculating the total implementation costs from the information provided in Chapter 3, this wage rate is used to convert hours of labor to dollar amounts.

Depreciation is the loss of value due to age, use, and obsolescence. Annual depreciation costs of off-stream watering devices and covered facilities are calculated by the straight line method. Annual depreciation cost is the sum of initial cost minus salvage value divided by the life expectancy. Initial cost refers to the initial cost of materials and is part of the implementation costs described in Chapter 3. Implementation costs provided in Chapter 3 did not always separate initial material costs from labor costs. In this case, material costs and labor costs are assumed to be equal and represent 50% each. No implementation cost for Enterprise No. 2's water trough was given since it was already on-site. However, it will be included in this analysis as an initial cost of 300 dollars and four hours of labor for installation. Total implementation cost for the water trough is 328 dollars.

The estimated salvage value for a water trough is zero, while a pasture pump is 50 dollars. The estimated salvage value for each covered facility is 20% of the initial cost of materials stated in Chapter 3. The life expectancy for a water trough and pasture pump is 5 years. The life expectancy for all covered facilities is 10 years.

Annual repair costs for the watering devices and covered facilities are estimated to be 4% of purchase price or original cost of materials. Annual interest costs, or alternative investment costs, will be calculated by multiplying the average investment by an 8% annual interest rate. Average investment is the sum of the implementation cost and estimated salvage value divided by 2. If the implementation cost was financed, the annual interest rate represents the loan rate. Otherwise, the annual interest rate represents the rate of return of the enterprise's next best investment alternative, or the opportunity cost of capital.

Partial budget analyses for implementing covered manure storage facilities, covered compost facilities, and off-stream watering devices in Enterprises No. 1,2,3, and 4 are given in the following paragraphs and tables.

Enterprise No. 1

Partial budget analyses for Enterprise No. 1 are shown in Tables 8.1 and 8.2. No annual added revenue or reduce expense followed the implementation of a covered manure compost bin and pasture pump. The main increased costs for the compost bin are from one hour of labor per week required to turn the pile. The total annual change in return to management following the implementation of both practices is -598 dollars, where 50% of the return is labor costs.

Enterprise No. 2

Enterprise No. 2 implemented a covered manure storage facility and an off-stream watering device. The manure storage facility and off-stream watering device changed the annual return to management by -397 and -67 dollars, respectively (Tables 8.3 and 8.4). Following the implementation of both practices, the total change in annual return to management is -464 dollars. Even though the implementation cost of the manure storage was greater than Enterprise No. 1's compost bin, the change in annual return to management is larger. The covered manure storage had no increase in labor costs as compared to the compost bin. Both off-stream watering devices implemented for Enterprises No. 1 and 2 resulted in similar changes in annual return to management.

Table 8.1. Partial budget analysis for implementing a covered manure compost bin for Enterprise No. 1.

Implemented Practice: Manure Compost Bin		
	Revenue and Expenses ($)	
1. Added Revenue	0	
2. Reduced Expense	0	
3. Added Revenue plus Reduced Expenses		0
4. Added Expenses.		
Depreciation	76	
Repairs	38	
Interest	42	
Increased Labor	364	
5. Reduced Revenue	0	
6. Added Expenses plus Reduced Revenue		520
7. Difference (Annual Change in Return to Management)		-520

Table 8.2. Partial budget analysis for implementing an off-stream watering device (pasture pump) for Enterprise No. 1.

Implemented Practice: Off-Stream Watering Device		
	Revenue and Expenses ($)	
1. Added Revenue	0	
2. Reduced Expense	0	
3. Added Revenue plus Reduced Expenses		0
4. Added Expenses		
Depreciation	39	
Repairs	18	
Interest	21	
5. Reduced Revenue	0	
6. Added Expenses plus Reduced Revenue		78
7. Difference (Annual Change in Return to Management)		-78

Table 8.3. Partial budget analysis for implementing a covered manure storage facility for Enterprise No. 2.

Implemented Practice: Covered Manure Storage		
	Revenue and Expenses ($)	
1. Added Revenue	0	
2. Reduced Expense	0	
3. Added Revenue plus Reduced Expenses		0
4. Added Expenses		
Depreciation	156	
Repairs	78	
Interest	163	
5. Reduced Revenue	0	
6. Added Expenses plus Reduced Revenue		397
7. Difference (Annual Change in Return to Management)		-397

Table 8.4. Partial budget analysis for implementing an off-stream watering device (water trough) for Enterprise No. 2.

Implemented Practice: Off-Stream Watering Device		
	Revenue and Expenses ($)	
1. Added Revenue	0	
2. Reduced Expense	0	
3. Added Revenue plus Reduced Expenses		0
4. Added Expenses		
Depreciation	24	
Repairs	12	
Interest	11	
5. Reduced Revenue	0	
6. Added Expenses plus Reduced Revenue		67
7. Difference (Annual Change in Return to Management)		-67

Enterprise No. 3

Enterprise No. 3 implemented a pasture pump and a covered manure storage facility. The facility is approximately the same size as implemented for Enterprise No. 2. The pasture pump was implemented for demonstration purposes, was completely subsidized, and was not designed to decrease the enterprise's pollution impacts. Therefore, it is not included in the analysis. Enterprise No. 3's annual change in return to management is -324 dollars (Table 8.5). Note that Enterprise No. 2 had similar results.

Table 8.5. Partial budget analysis for implementing a covered manure storage facility for Enterprise No. 3.

Implemented Practice: Covered Manure Storage

	Revenue and Expenses ($)	
1. Added Revenue	0	
2. Reduced Expense	0	
3. Added Revenue plus Reduced Expenses		0
4. Added Expenses		
Depreciation	134	
Repairs	67	
Interest	123	
5. Reduced Revenue	0	
6. Added Expenses plus Reduced Revenue		324
7. Difference (Annual Change in Return to Management)		-324

Enterprise No. 4

Enterprise No. 4 installed a covered manure compost facility larger than the other three manure storages. Prior to implementing the practice, the collected manure was transported off-site due to the presence of possible pathogenic bacteria that could infect the animals within the operation. Now, the manure is spread on the pasture since the composted manure reaches high temperatures and lowers the potential presence of pathogenic bacteria. The implemented practice decreases annual fertilizer costs by 500 dollars and is shown in Table 8.6 as a reduced expense.

Prior management costs of collecting manure, piling it uncovered, and hauling it off-site were found to be equivalent to present costs of manure collection, pile turning, and land spreading. Therefore, these costs were omitted from the analysis. The tractor and labor hours for the operation did not change after implementing the practice and are also not included in the analysis.

Enterprise No. 4 has -704 dollars annual change in return to management and is the lowest of all four enterprises. The high implementation cost of the facility affects the depreciation and interest expenses and is the primary factor in lowering the annual change in return.. Recall from Chapter 3 that approximately 75% of the implementation costs were subsidized and are not included in the analysis. However, this analysis illustrates how BMPs with high implementation costs will lower annual returns to management unless added revenue and reduced expenses are associated with the practice.

Table 8.6. Partial budget analysis for implementing a covered compost facility for Enterprise No. 4.

Implemented Practice: Covered Compost Facility

	Revenue and Expenses ($)	
1. Added Revenue	0	
2. Reduced Expense	500	
3. Added Revenue plus Reduced Expenses		500
4. Added Expenses		
Depreciation	490	
Repairs	245	
Interest	469	
5. Reduced Revenue	0	
6. Added Expenses plus Reduced Revenue		1204
7. Difference (Annual Change in Return to Management)		-704

8.4 Conclusion

The partial budget analyses of implementing BMPs show various changes in annual monetary returns to management for the four enterprises. The smallest enterprise has the second lowest change in annual return due to a one hour per week labor increase. The largest enterprise had the lowest change in annual return to management due to the largest implementation cost. The analyses suggest that BMPs provide no positive change in annual monetary returns to management, and implementation and labor costs are the most critical factors in lowering annual returns.

CHAPTER 9

CONCLUSIONS

Off-stream watering areas without animal access to streams and covered manure storages are two BMPs analyzed for their effectiveness in reducing the bacterial, nitrogen, and phosphorus water quality impacts of four SCAEs. Off-stream watering areas were successful in reducing the time animals spend at streams by 75%. The analysis assumed that defecations at the stream were reduced by 75% and defecations in the off-stream watering area increased by 75% when an off-stream watering area was implemented. Therefore, this practice is most effective in dry weather when the defecations in the off-stream watering area do not enter surface runoff or leach to groundwater. The implementation costs of these watering areas were less than 400 dollars with some of these costs subsidized by government agencies. The change in annual monetary return to management was more than -100 dollars. Both the effectiveness in reducing water quality impacts and the incurred costs of managing the practice make this BMP a potential alternative to denying animal access to streams.

Covered manure storage facilities that replace uncovered manure piles were 100% effective in reducing bacteria, nitrogen, and phosphorus from entering surface runoff or leaching to groundwater. Based on original water quality impacts of uncovered manure piles, the largest amount of bacteria and nutrients reduced were for winter days of continuous rain and manure piles located close to a stream. Implementation costs ranged from 1000 to 13,000 dollars with some of these costs subsidized by government agencies. Changes in annual monetary returns to management ranged from -300 to -700 dollars.

Considering potential pollution reductions and costs to landowners and government agencies providing subsidies, discretion should be used to implement this practice only in areas with the most potential pollution problems.

Miner et al.'s (1993) study of the extent and manure management of SCAEs in the Tualatin River Basin predicted 28% of the SCAEs allow stream access and 44% have uncovered manure piles. Implementing these BMPs in all SCAEs would eliminate a majority of the associated water quality impacts.

CHAPTER 10

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APPENDICES

APPENDIX A

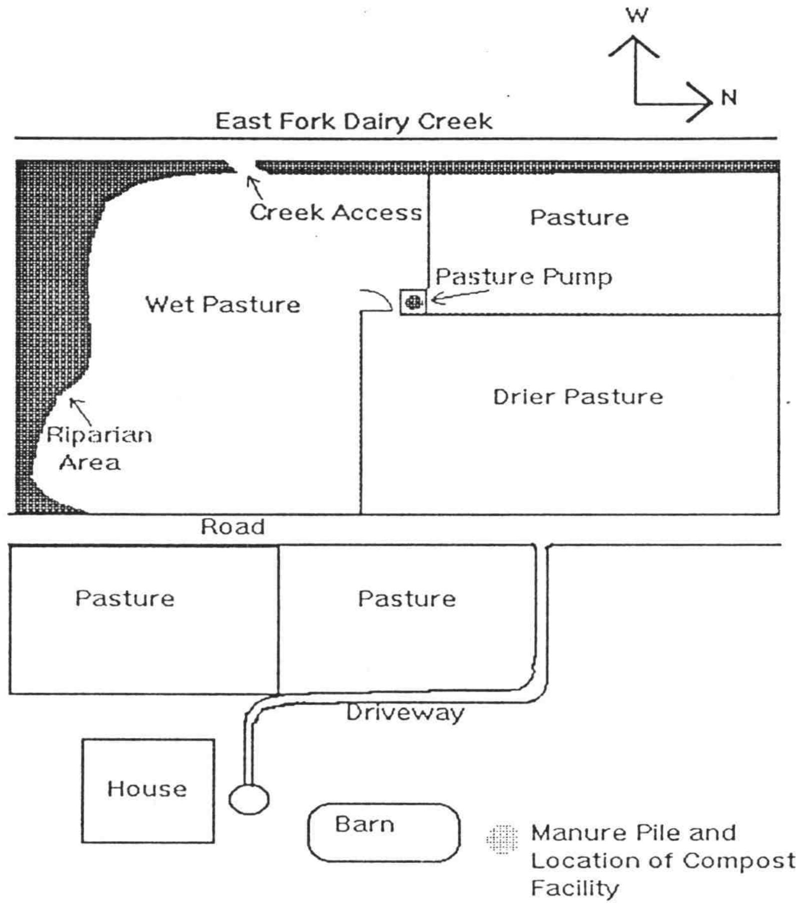


Figure 1. Enterprise No. 1: two horse operation in the Tualatin River Basin, 1993.

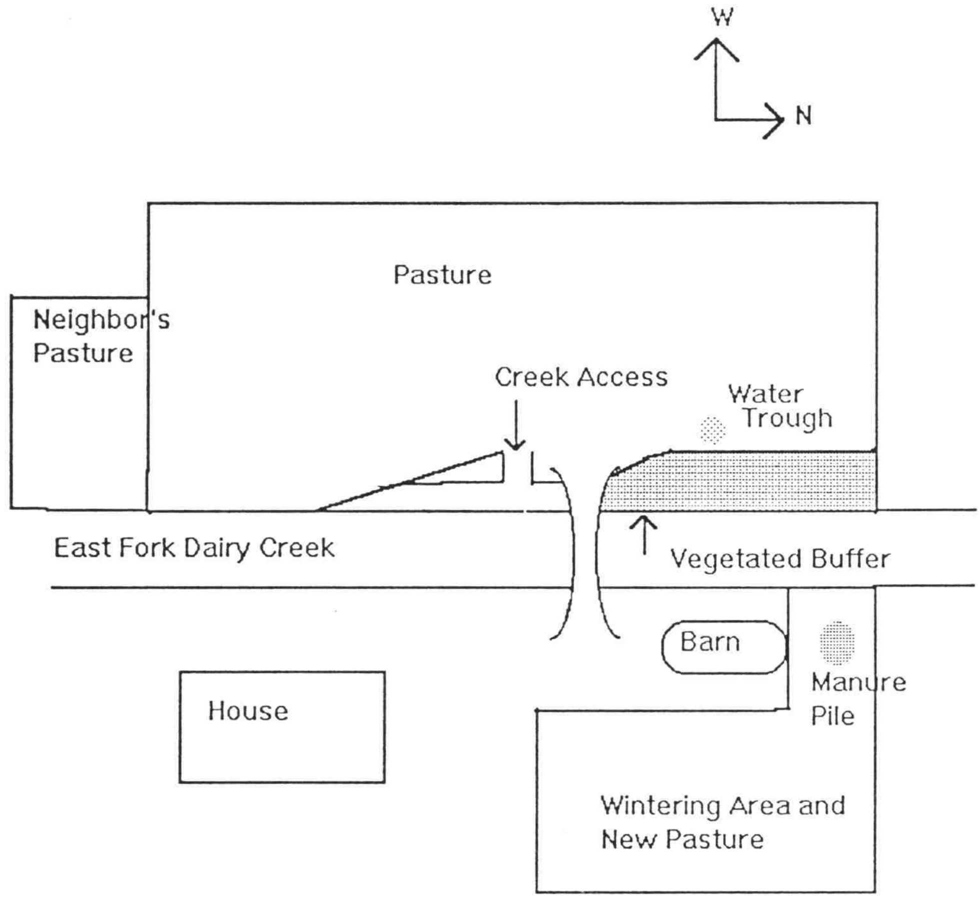


Figure 2. Enterprise No. 2: small beef cow and swine operation in the Tualatin River Basin, 1993.

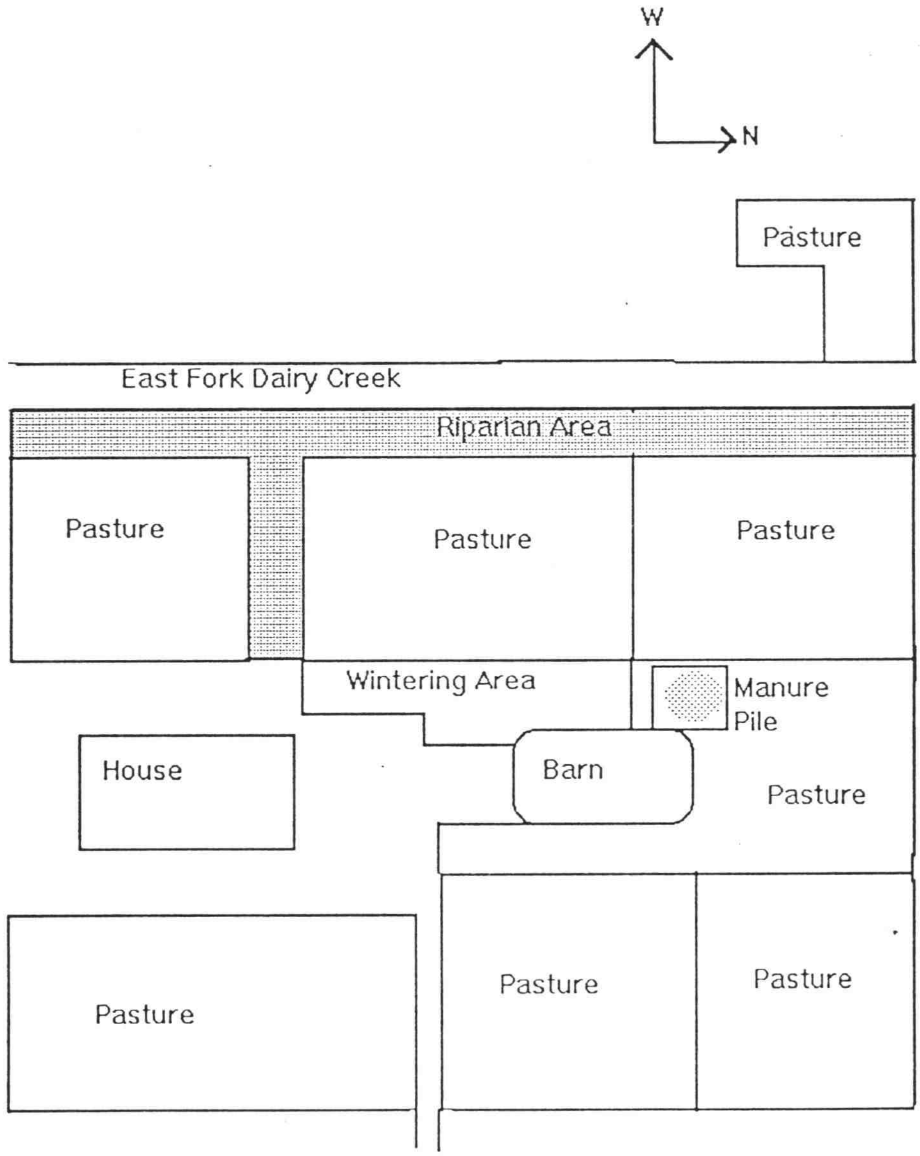


Figure 3. Enterprise No. 3: small beef cow operation in the Tualatin River Basin, 1993.

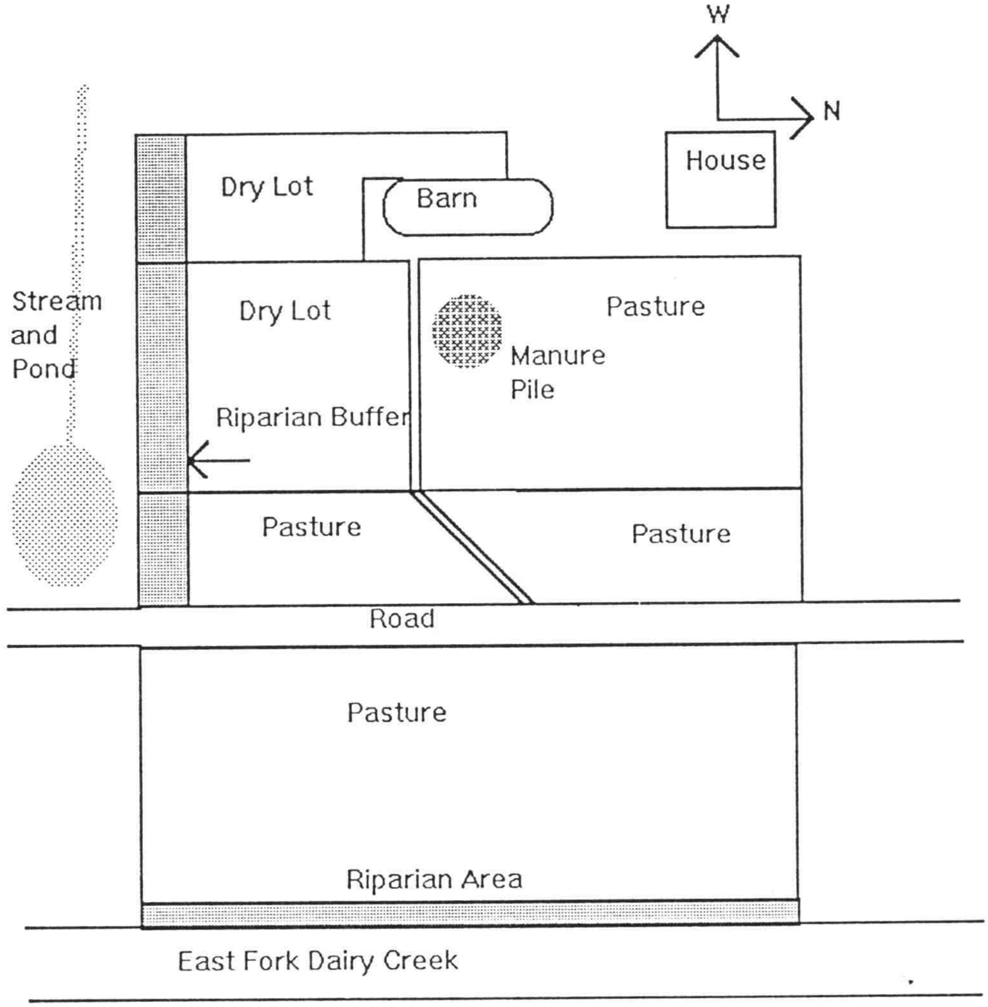


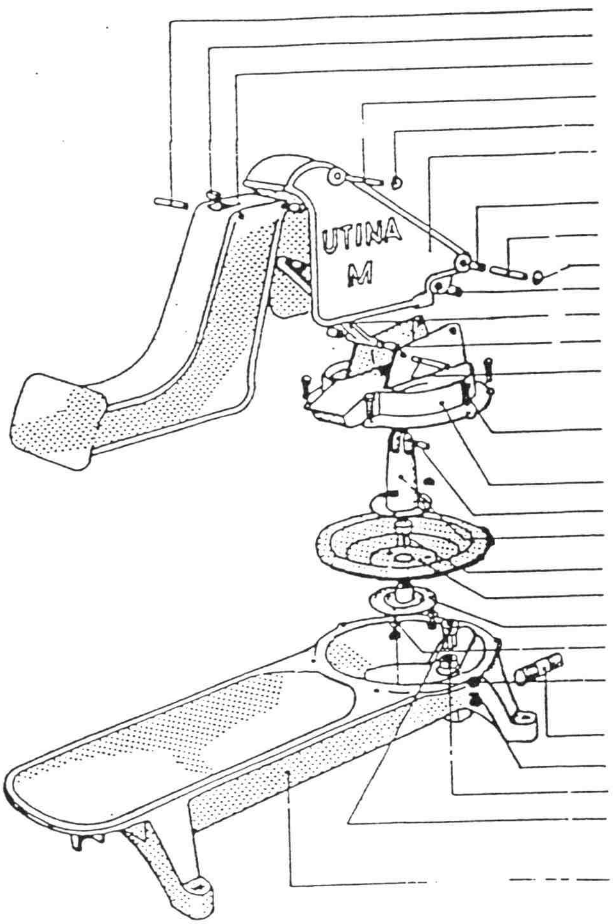
Figure 4. Enterprise No. 4: medium size horse operation in the Tualatin River Basin, 1993.

APPENDIX B

UTINA

409 Mayville Street
THERESA, WISCONSIN 53091
(414) 488-3221

PARTS LIST FOR PASTURE PUMP
Order # 330



Part No.	Part
2.042431	Bolt, dia. 10x80
2.870012	Plastic sleeve
2.870064	Pressure lever w/sleeves
2.042429	Bolt dia. 10x172
2.870014	Cap (bolt fastening)
2.870063	Suction lever w/sleeves
2.870012	Plastic sleeve 19 lg.
2.042430	Bolt, dia. 10x88
2.870015	Cap (hole fastening)
2.870013	Plast. sleeve/bushing 13 lg
2.870005	Support lever w.sleeve/bush.
2.870012	Plastic sleeve 19 lg.
2.042430	Bolt, 10x88
2.000673	Hex bolt M 8 x 35 w. nut
2.870002	Pump, upper section
2.042435	Bolt, 10x38
2.870006	Diaphragm piston
2.031121	Valve cone, rubber
2.031115	Diaphragm, rubber
2.870007	Diaphragm, plate
2.035015	Klingerit seal 9x16x2
2.000674	Hex bolt M 8 x 30 w. nut
2.010201	Hose connection nipple 1"
2.002393	Disc dia. 8.4
2.870060	Sleeve/bushing 25 lg.
2.031121	Valve cone, rubber
2.870071	Drinking trough w/sleeve
2.882300	Set bolts + sleeves/bush.

Figure 5. Pasture pump used as an off-stream watering device in Enterprises No.1 and 3 in the Tualatin River Basin, 1993.

Table 1B. Data from pasture pump test with dairy cows.

Date	Time	Inches of Water Drank	Amount Drank (L's)	Amount Drank (gal.'s)
9-Jul	1120	0	0	0.0
	1428	8.750	114	30.1
	1820	4.500	54	14.3
	2045	4.700	57	15.1
10-Jul	730	1.100	12	3.2
	1200	16.700	254	67.1
	1615	10.250	136	35.9
	2045	15.850	236	62.4
11-Jul	840	2.500	28	7.4
	1206	6.400	78	20.6
	2015	16.650	254	67.1
12-Jul	800	17.300	265	70.0
	1122	14.875	218	57.6
	1432	8.750	114	30.1
	1731	2.375	26	6.9
	2045	13.250	186	49.1
13-Jul	830	9.300	121	32.0
	1120	10.500	140	37.0
	1450	4.875	59	15.6
	1750	4.625	56	14.8
	2145	9.100	118	31.2
14-Jul	820	4.150	50	13.2
	1128	-0.450		0.0
	1425	0.000	0	0.0
	1728	8.500	109	28.8
	2055	3.000	34	9.0
15-Jul	835	12.900	180	47.6
	1100	10.300	137	36.2
	1426	9.250	121	32.0
	1729	9.750	128	33.8
	2035	5.125	62	16.4
16-Jul	825	7.500	94	24.8
	1128	6.500	80	21.1
	1433	8.750	114	30.1
	Did Trough Meas. til 1610			0.0
	1730	0.563	6	1.6
	2040	9.875	130	34.3
17-Jul	805	1.875	20	5.3
	1120	7.188	88	23.2
	1423	8.375	106	28.0
	2030	13.188	184	48.6
18-Jul	840	5.250	64	16.9
	1130	9.250	121	32.0
	1500	13.750	195	51.5
	2030	10.750	145	38.3
19-Jul	815	6.250	76	20.1

Table 1B. continued.

Date	Time	Inches of Water Drank	Amount Drank (L's)	Amount Drank (gal.'s)
19-Jul	1123	13.063	184	48.6
	1437	10.625	142	37.5
	1732	5.063	61	16.1
	2030	12.188	169	44.6
20-Jul	830	9.000	117	30.9
	1128	14.875	218	57.6
	1427	4.000	47	12.4
	1732	7.313	91	24.0
	2030	10.000	132	34.9
21-Jul	830	3.500	41	10.8
	1122	14.125	202	53.4
	1430	10.125	134	35.4
	1730	0.375	4	1.1
	2030	3.250	37	9.8
22-Jul	830	5.000	60	15.9
	1118	0.125	1	0.3
	1438	16.563	250	66.1
	1740	3.625	42	11.1
	2030	9.188	120	31.7
23-Jul	955	9.000	117	30.9
	1128	14.500	209	55.2

APPENDIX C

Table 1C. Data summary for off-stream watering area study with four cows (Enterprise No. 2).

Time of Chang	Julian Day	Total Minutes	Water Access	Errors	Data Not Included In Analysis (*)
1400	219	0	Both		*
	220	0	Both		*
?	221	0	Both		*
	222	0	Both		*
	223	0	Both		*
	224	0	Both		*
1522	225	0	Stream		*
	226	0	Stream		*
	227	0	Stream		*
	228	0	Stream		*
1035	229	0	Stream		*
	230	60	Stream	Cows Lured	*
	231	9	Stream	Cows Lured	*
	232	116	Stream	Cows Lured	*
1800	233	130	Stream	Cows Lured	*
	234	84	Stream		
	235	64	Stream		
	236	153	Stream		
1055	237	66	Stream		
	238	28	Stream		
	239	37	Stream		
	240	72	Stream		
	241	30	Stream		
	242	57	Stream		
	243	41	Stream		
	244	76	Stream		
	245	45	Stream		
	246	56	Stream		
	247	44	Stream		
	248	76	Stream		
	249	46	Stream		
	250	44	Stream		
1700	251	20	CHANGE	Partial Day	*
	252		Both	Lost Data	*
	253		Both	Lost Data	*
	254		Both	Lost Data	*
	255		Both	Lost Data	*
1520	256		Both	Lost Data	*
	257	51	Both		
	258	9	Both		
	259	11	Both		
1007	260	14	Both		
1415	261	9	Both		
	262	47	Both		
	263	5	Both		
	264	0	Both		

Table 1C. continued.

Time of Chang	Julian Day	Total Minutes	Water Access	Errors	Data Not Included In Analysis (*)
	265	2	Both		
	266	11	Both		
1400	267	3	Both		

Raw Data from Off-Stream Watering Study with Four Cows

Cows have option   Started on 219 at 1400 and Changed on 221 at ?

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	220	2336	48	0	1	64.77	12.62	60.61

Cows have option   Changed on 221 at ? and 225 at 1522

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	223	534	51	0	1	55.88	12.55	54.8

Cows have no option   Changed on 225 at 1522 and 229 at 1035

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	227	748	19	0	1	55.87	12.42	55.41
111	229	554	34	0	1	51.74	12.36	50.34

Cows have no option   Changed on 229 at 1035 and 233 at 1800   Cows lured to stream

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	230	747	52	0	1	56.02	12.34	55.95
111	230	1510	38	0	1	104	12.4	96.1
111	230	1510	42	0	1	104	12.4	96.2
111	230	1511	21	0	1	104	12.4	96.9
111	230	1511	22	0	1	104	12.38	96.9
104	230	1512	45	1	0	104.2	12.38	96.4
104	230	1512	46	2	0	104.2	12.37	96.4
104	230	1512	48	2	0	104.2	12.38	96.4
104	230	1512	49	2	0	104.2	12.38	96.4
104	230	1512	54	2	0	104.2	12.38	96.6
104	230	1512	57	1	0	104.2	12.38	97.1
104	230	1513	6	2	0	104.2	12.38	97.4
104	230	1513	27	1	0	104.3	12.38	96.8
104	230	1513	28	1	0	104.3	12.39	96.9
104	230	1536	23	1	0	106.1	12.39	97.5
111	230	1608	58	0	1	108	12.4	99.3
104	230	1609	13	1	0	108	12.4	98.9
104	230	1609	14	3	0	108	12.4	98.8
104	230	1609	15	1	0	108	12.4	98.8
104	230	1609	16	1	0	108	12.4	98.8
104	230	1609	17	1	0	108	12.39	98.8
104	230	1609	19	2	0	108	12.4	98.8
104	230	1613	37	1	0	108.3	12.4	98.5
111	230	1622	7	0	1	108.8	12.4	98.6
111	230	1639	45	0	1	109.8	12.4	98.7
111	230	1732	14	0	1	110.3	12.4	98.1
104	230	1732	32	2	0	110.3	12.4	98.5

104	230	1737	8	1	0	110.7	12.39	98.6
111	230	1804	33	0	1	112.4	12.4	99.2
104	230	1806	19	1	0	112.5	12.39	99.1
111	230	1942	26	0	1	100.2	12.38	87.9
104	230	1959	37	1	0	97.9	12.38	86.1
111	231	608	41	0	1	67.82	12.34	65.72
111	231	614	56	0	1	67.7	12.32	66.04
104	231	623	21	1	0	67.59	12.32	65.41
111	231	738	9	0	1	66.54	12.33	64.73
104	231	738	56	1	0	66.52	12.32	64.56
111	232	624	36	0	1	63.95	12.28	62.29
104	232	625	44	1	0	63.93	12.28	61.81
111	232	643	40	0	1	63.49	12.28	61.98
104	232	652	15	1	0	63.35	12.29	62.07
104	232	652	31	1	0	63.31	12.28	62.03
104	232	711	2	1	0	63.12	12.28	61.68
104	232	711	5	1	0	63.12	12.28	61.76
111	232	714	20	0	1	63.12	12.28	61.91
111	232	716	40	0	1	63.06	12.26	61.84
104	232	718	35	1	0	63.06	12.26	61.69
104	232	718	37	1	0	63.06	12.26	61.69
111	232	1705	51	0	1	86.7	12.31	80.5
104	232	1710	1	1	0	86.6	12.31	80.4
111	232	1710	22	0	1	86.6	12.31	80.3
111	232	1717	50	0	1	86.5	12.31	80.1
111	232	1718	0	0	1	86.5	12.31	80.2
111	232	1718	20	0	1	86.5	12.31	80.4
111	232	1722	49	0	1	86.4	12.29	80.1
104	232	1725	11	1	0	86.4	12.31	80.1
111	232	1725	19	0	1	86.3	12.31	80.1
111	232	1745	12	0	1	85.6	12.3	79.1
104	232	1745	14	1	0	85.6	12.31	79.1
104	232	1745	19	1	0	85.7	12.31	79.1
104	232	1745	22	1	0	85.7	12.31	79.1
104	232	1859	37	1	0	82.7	12.29	76.7
111	233	615	44	0	1	60.9	12.24	60.29
111	233	616	2	0	1	60.88	12.25	60.27
111	233	617	54	0	1	60.86	12.24	60.4
111	233	620	54	0	1	60.8	12.24	59.43
104	233	630	32	1	0	60.72	12.26	59.73
104	233	640	26	1	0	60.59	12.24	59.83
111	233	807	1	0	1	60.36	12.25	60.05
111	233	807	33	0	1	60.36	12.24	60.05
111	233	808	8	0	1	60.37	12.24	60.15
104	233	808	22	1	0	60.36	12.24	60.13
104	233	808	52	1	0	60.39	12.24	60.17
111	233	809	8	0	1	60.37	12.24	60.15
104	233	814	39	1	0	60.47	12.24	60.01
104	233	821	6	1	0	60.62	12.25	60.47
104	233	825	38	1	0	60.74	12.24	60.51
111	233	825	54	0	1	60.77	12.24	60.55
104	233	826	10	1	0	60.76	12.23	60.53
104	233	826	16	1	0	60.77	12.23	60.55

104	233	826	23	1	0	60.76	12.23	60.53
104	233	826	31	1	0	60.77	12.23	60.55
104	233	826	33	1	0	60.77	12.23	60.55
104	233	826	40	1	0	60.76	12.23	60.53
104	233	826	44	2	0	60.77	12.23	60.55
104	233	826	48	1	0	60.77	12.23	60.55
104	233	826	59	1	0	60.81	12.23	60.51
104	233	827	19	1	0	60.79	12.21	60.49
104	233	827	24	1	0	60.83	12.22	60.53
111	233	829	6	0	1	60.85	12.23	60.62
104	233	840	42	1	0	61.19	12.23	60.74
111	233	929	51	0	1	63.28	12.24	62.75
104	233	930	30	1	0	63.31	12.25	62.71
111	233	1101	19	0	1	70.5	12.26	69.26
111	233	1101	35	0	1	70.5	12.26	70.2
111	233	1102	24	0	1	70.8	12.25	70.2
104	233	1104	49	1	0	71.4	12.26	71.5
104	233	1110	48	1	0	72.9	12.26	71.8
104	233	1111	36	1	0	73.2	12.25	73.3
111	233	1455	50	0	1	99.5	12.28	89.5
104	233	1455	53	1	0	99.5	12.28	89.6
111	233	1455	54	0	1	99.5	12.28	89.6
111	233	1456	17	0	1	99.5	12.27	89.5
111	233	1458	16	0	1	99.6	12.28	89.9
104	233	1503	33	1	0	99.7	12.28	89.5
104	233	1503	36	1	0	99.8	12.28	89.6
111	233	1727	54	0	1	97.1	12.28	87
104	233	1729	4	1	0	97.2	12.27	86.7
111	233	1735	48	0	1	97.5	12.29	86.2
111	233	1739	4	0	1	97.5	12.28	85.9
104	233	1745	49	1	0	97.3	12.28	85.1
104	233	1750	13	1	0	97	12.28	85.5

Cows have no option   Changed on 233 at 1800 and 237 at 1055

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	234	703	20	0	1	56	12	55
111	234	704	39	0	1	56	12	56
104	234	707	17	1	0	56	12	56
104	234	707	22	1	0	56	12	55
104	234	707	34	1	0	56	12	55
104	234	707	36	1	0	56	12	55
104	234	710	23	1	0	56	12	56
104	234	720	31	1	0	56	12	56
104	234	721	17	1	0	56	12	56
111	234	726	33	0	1	56	12	56
104	234	729	47	1	0	56	12	56
104	234	729	48	1	0	56	12	56
111	234	729	51	0	1	56	12	56
111	234	730	12	0	1	56	12	56
104	234	733	6	1	0	56	12	56

111	234	735	7	0	1	56	12	56
104	234	737	15	1	0	56	12	56
111	234	1050	9	0	1	68	12	69
104	234	1054	24	1	0	69	12	69
111	234	1222	48	0	1	80	12	79
111	234	1222	54	0	1	80	12	79
111	234	1223	21	0	1	80	12	79
104	234	1224	33	1	0	80	12	78
104	234	1225	39	1	0	80	12	79
104	234	1225	42	1	0	80	12	79
111	234	1545	45	0	1	104	12	94
111	234	1546	40	0	1	104	12	94
104	234	1548	1	1	0	104	12	93
104	234	1549	1	1	0	104	12	94
111	234	1549	33	0	1	104	12	93
111	234	1556	7	0	1	103	12	92
104	234	1556	42	1	0	103	12	92
104	234	1559	28	1	0	103	12	92
111	234	1651	48	0	1	99	12	90
104	234	1652	32	1	0	99	12	90
104	234	1655	36	1	0	99	12	90
111	234	1657	38	0	1	99	12	90
104	234	1700	28	1	0	99	12	89
111	234	1700	30	0	1	99	12	89
111	234	1853	5	0	1	90	12	81
104	234	1902	24	1	0	89	12	81
111	235	639	59	0	1	62	12	60
104	235	647	27	1	0	62	12	60
104	235	651	27	1	0	62	12	59
111	235	655	59	0	1	61	12	59
104	235	659	21	1	0	61	12	59
111	235	659	26	0	1	61	12	59
111	235	1241	27	0	1	71	12	69
104	235	1243	37	1	0	72	12	71
111	235	1317	24	0	1	74	12	71
104	235	1318	47	1	0	74	12	71
111	235	1411	51	0	1	80	12	77
104	235	1417	16	1	0	81	12	76
111	235	1728	16	0	1	87	12	77
104	235	1730	20	1	0	87	12	77
104	235	1730	45	1	0	87	12	77
111	235	1730	52	0	1	87	12	77
111	235	1759	56	0	1	87	12	77
111	235	1801	30	0	1	87	12	77
111	235	1803	21	0	1	87	12	77
104	235	1814	25	1	0	87	12	77
104	235	1821	38	1	0	87	12	77
111	235	1821	44	0	1	87	12	77
111	235	1837	31	0	1	87	12	76
111	235	1839	11	0	1	87	12	75
104	235	1840	56	1	0	87	12	75
104	235	1842	59	1	0	86	12	75
111	236	645	3	0	1	47	12	46

111	236	645	11	0	1	47	12	46
104	236	647	10	2	0	47	12	45
104	236	647	12	1	0	47	12	45
111	236	647	20	0	1	47	12	45
104	236	647	23	1	0	47	12	45
111	236	715	40	0	1	46	12	46
104	236	903	4	1	0	49	12	51
104	236	910	20	1	0	50	12	52
111	236	910	25	0	1	50	12	51
104	236	910	48	1	0	50	12	51
111	236	1157	34	0	1	64	12	65
111	236	1158	14	0	1	64	12	64
104	236	1201	9	1	0	65	12	64
104	236	1202	16	1	0	65	12	64
111	236	1638	43	0	1	79	12	73
111	236	1639	14	0	1	79	12	73
104	236	1642	36	1	0	80	12	73
104	236	1643	16	1	0	80	12	73
111	236	1703	17	0	1	82	12	75
111	236	1703	23	0	1	82	12	75
104	236	1703	33	1	0	82	12	75
104	236	1707	39	1	0	83	12	75
104	236	1709	53	1	0	83	12	76
111	236	1726	45	0	1	85	12	76
104	236	1729	27	1	0	86	12	76
111	236	1843	22	0	1	87	12	75
104	236	1849	57	1	0	86	12	74
111	237	608	27	0	1	45	12	45
104	237	618	14	1	0	45	12	45
111	237	626	15	0	1	45	12	45
111	237	626	21	0	1	45	12	45
111	237	626	49	0	1	45	12	45
104	237	627	12	1	0	45	12	45
104	237	627	22	1	0	45	12	45
104	237	627	26	1	0	45	12	45
104	237	629	11	1	0	45	12	45
111	237	956	22	0	2	52	12	54
104	237	958	12	1	0	52	12	53

Cows have no option   Changed on 237 at 1055 and on 251 at 1700

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	237	1144	17	0	1	65.13	12.11	65.28
111	237	1144	58	0	1	65.23	12.09	65.01
104	237	1154	42	1	0	66.43	12.11	64.77
104	237	1155	42	1	0	66.49	12.1	65.29
111	237	1529	34	0	1	88.2	12.13	81.1
104	237	1530	56	1	0	88.2	12.14	79
111	237	1655	28	0	1	94.1	12.15	83.2
104	237	1659	32	1	0	94.2	12.14	83.1
111	237	1732	4	0	1	95.7	12.14	84

104	237	1745	40	1	0	96.4	12.15	84.2
111	237	1828	41	0	1	95.6	12.13	81.5
104	237	1831	22	1	0	95.5	12.14	80.8
111	237	1831	25	0	1	95.4	12.15	80.8
111	237	1835	24	0	1	94.8	12.13	80.8
111	237	1835	27	0	1	94.9	12.14	80.8
104	237	1837	26	1	0	94.5	12.14	80.3
104	237	1838	1	1	0	94.4	12.14	80.3
111	238	636	47	0	1	49.67	12.06	48.11
111	238	637	21	0	1	49.65	12.06	48.09
111	238	637	35	0	1	49.65	12.05	48.09
104	238	637	47	1	0	49.65	12.05	48.17
104	238	638	24	1	0	49.61	12.05	47.9
104	238	638	34	1	0	49.61	12.05	47.75
111	238	641	50	0	1	49.52	12.07	48.28
104	238	648	43	1	0	49.34	12.05	47.94
111	238	648	50	0	1	49.34	12.06	47.94
111	238	745	27	0	1	48.52	12.07	48.44
111	238	1141	51	0	1	69.29	12.07	71.4
104	238	1143	34	1	0	69.54	12.08	71.4
111	238	1143	37	0	1	69.52	12.09	71.2
111	238	1430	46	0	1	94.3	12.11	89.1
111	238	1431	31	0	1	94.4	12.11	88.3
111	238	1432	55	0	1	94.6	12.11	88.5
104	238	1433	47	1	0	94.7	12.11	89.3
104	238	1433	58	1	0	94.7	12.11	89
111	238	1528	50	0	1	100.7	12.13	92
104	238	1530	23	1	0	100.8	12.12	92
111	238	1624	57	0	1	105.5	12.13	94.4
111	238	1628	16	0	1	105.7	12.13	94.3
104	238	1629	45	1	0	105.8	12.13	94.1
111	238	1631	31	0	1	106	12.13	94.4
104	238	1634	29	1	0	106.1	12.12	94.8
111	238	1634	34	0	1	106.1	12.13	94.9
104	238	1634	41	1	0	106.2	12.13	94.9
111	238	1843	22	0	1	103.8	12.12	87.9
111	238	1843	28	0	1	103.8	12.12	88
104	238	1846	35	1	0	103.1	12.12	86.8
111	238	1846	54	0	1	103.1	12.12	86.9
104	238	1850	23	1	0	102.4	12.13	87.1
111	238	1850	27	0	1	102.3	12.13	87.1
111	239	619	1	0	1	54.97	12.03	53.12
111	239	620	44	0	1	54.92	12.03	53.07
104	239	621	44	1	0	54.92	12.04	53.07
104	239	628	23	1	0	54.75	12.03	53.29
111	239	1316	51	0	1	82.2	12.06	79.9
111	239	1317	2	0	1	82.3	12.06	79.9
104	239	1318	58	1	0	82.6	12.06	79.6
104	239	1319	57	1	0	82.7	12.07	79
111	239	1403	14	0	1	85.9	12.07	80.5
104	239	1408	25	1	0	86.1	12.07	81.6
111	239	1528	27	0	1	90.9	12.08	85.1
104	239	1529	40	1	0	91	12.07	84.8

111	239	1814	43	0	2	93.8	12.08	82.7
111	239	1814	51	0	1	93.8	12.07	82.9
104	239	1818	14	1	0	93.7	12.06	82.5
104	239	1820	37	1	0	93.6	12.06	82.9
111	239	1832	38	0	1	92.6	12.07	81.1
111	239	1832	48	0	1	92.6	12.06	81.3
104	239	1834	5	1	0	92.5	12.06	81.2
104	239	1835	2	1	0	92.3	12.07	81.1
111	240	702	22	0	1	52.01	11.99	51.62
104	240	715	49	1	0	51.99	11.99	51.06
111	240	1054	23	0	1	60.26	12.01	61.77
111	240	1054	59	0	1	60.31	12.01	61.68
104	240	1056	51	1	0	60.45	11.98	61.81
111	240	1056	52	0	1	60.47	11.98	61.83
104	240	1057	47	1	0	60.52	11.99	61.74
111	240	1103	51	0	1	60.97	12	61.72
104	240	1112	53	1	0	61.68	12.01	62.43
111	240	1352	15	0	1	82.3	12.03	78.8
111	240	1353	40	0	1	82.5	12.03	79
104	240	1354	3	1	0	82.6	12.03	78.7
104	240	1354	34	1	0	82.7	12.03	78.1
104	240	1515	8	1	0	88.2	12.05	80.2
104	240	1534	59	1	0	88.7	12.04	81.6
111	240	1535	1	0	1	88.8	12.05	81.6
111	240	1621	29	0	1	92.8	12.05	83.5
111	240	1621	48	0	1	92.8	12.05	83.4
111	240	1626	19	0	1	93.1	12.05	83.8
104	240	1631	35	1	0	93.2	12.05	84.3
104	240	1632	36	1	0	93.3	12.05	84
104	240	1632	42	1	1	93.3	12.04	84
111	240	1632	42	0	1	93.3	12.04	84
104	240	1632	46	1	0	93.3	12.04	84
111	240	1632	49	0	1	93.3	12.04	84
111	240	1801	41	0	1	95.3	12.04	83.6
111	240	1802	47	0	1	95.3	12.04	83.7
111	240	1803	10	0	1	95.3	12.04	83.5
104	240	1806	45	1	0	95.3	12.04	83.4
104	240	1808	27	1	0	95.2	12.04	83.4
104	240	1808	35	1	0	95.2	12.04	83.4
111	240	1928	42	0	1	86.1	12.03	75.4
111	241	812	19	0	1	52.48	11.97	52.63
111	241	1114	30	0	1	67.74	11.98	68.94
111	241	1133	52	0	1	70.2	12	72.6
111	241	1424	9	0	1	94.2	12.01	88.1
104	241	1424	30	1	0	94.2	12.02	88
111	241	1424	53	0	1	94.3	12.02	88
111	241	1425	6	0	1	94.3	12.02	88
111	241	1425	27	0	1	94.4	12.02	88.5
104	241	1427	44	1	0	94.7	12.02	88.7
104	241	1428	49	2	0	94.9	12.03	88.5
104	241	1429	42	1	0	95	12.03	88.9
111	241	1701	14	0	1	107.9	12.04	95.3
111	241	1701	52	0	1	107.9	12.04	95.6

104	241	1705	9	1	0	108	12.03	95.4
104	241	1706	42	1	0	108	12.03	95.5
111	241	1745	15	0	1	109.2	12.03	94.9
104	241	1747	57	1	0	109.3	12.03	95
111	241	1748	10	0	1	109.2	12.04	95.2
111	241	1850	23	0	1	103.8	12.02	87.7
104	241	1857	20	1	0	102.5	12.01	86.9
111	242	631	29	0	1	53.07	11.92	51.83
111	242	631	54	0	1	53.08	11.92	51.85
111	242	632	24	0	1	53.05	11.92	51.81
104	242	633	14	1	0	53.03	11.93	51.41
111	242	633	24	0	1	53.01	11.92	51.47
104	242	635	30	1	0	52.96	11.92	51.72
104	242	635	40	1	0	52.96	11.94	51.26
104	242	636	22	1	0	52.94	11.92	51.7
111	242	949	34	0	1	56.49	11.92	60.07
111	242	949	54	0	1	56.52	11.92	60.34
111	242	950	26	0	1	56.54	11.93	60.36
104	242	954	42	1	0	56.78	11.93	60.29
104	242	956	29	1	0	56.9	11.93	60.48
104	242	958	44	1	0	57.07	11.92	60.57
111	242	1519	18	0	1	103.4	12	95.3
104	242	1520	16	1	0	103.5	12	96.1
111	242	1520	19	0	1	103.5	12	96.4
111	242	1530	34	0	1	104.4	11.99	96.2
104	242	1536	12	1	0	105	12	96.9
111	242	1653	49	0	1	112	12.01	100.2
104	242	1659	20	1	0	112.3	12.01	100.5
111	242	1659	23	0	1	112.2	12.01	100.5
111	242	1716	44	0	1	112.8	12.01	100.5
111	242	1717	32	0	1	112.9	12.01	100.5
104	242	1719	25	1	0	112.9	12.01	100.3
104	242	1719	43	1	0	112.9	12.01	100.6
111	242	1852	1	0	1	107.1	11.99	91.1
104	242	1858	6	1	0	105.8	12	90.6
111	243	626	5	0	1	55.41	11.89	54.03
111	243	627	7	0	1	55.38	11.9	54.3
111	243	627	11	0	1	55.38	11.89	54.23
111	243	627	19	0	1	55.36	11.9	54.28
111	243	627	21	0	1	55.36	11.9	54.28
104	243	627	23	1	0	55.36	11.88	54.28
104	243	627	26	1	0	55.38	11.88	54.3
104	243	636	7	1	0	55.16	11.9	53.62
111	243	828	32	0	1	54.21	11.88	54.67
104	243	837	26	1	0	54.45	11.9	55.6
111	243	1347	52	0	1	93.9	11.95	90.1
111	243	1347	54	0	1	93.9	11.95	90.1
111	243	1347	55	0	1	93.9	11.94	90.2
111	243	1348	16	0	1	94	11.94	90.5
111	243	1348	21	0	1	93.9	11.94	90.5
104	243	1350	39	1	0	94.3	11.94	90.4
104	243	1352	7	1	0	94.4	11.94	90.1
104	243	1353	6	1	0	94.5	11.94	90.3

111	243	1652	50	0	1	102.9	11.96	93.1
104	243	1654	52	1	0	102.9	11.96	92.5
111	243	1757	1	0	1	101.1	11.95	90.9
104	243	1801	4	1	0	101.1	11.95	90.1
111	243	1908	14	0	1	95.8	11.94	85.4
104	243	1913	52	1	0	95.2	11.94	84.6
111	244	555	36	0	1	56.31	11.86	54.92
104	244	619	56	1	0	55.66	11.87	53.66
104	244	619	57	1	0	55.62	11.86	53.62
111	244	620	7	0	1	55.66	11.87	53.97
111	244	840	41	0	1	54.52	11.85	55.21
111	244	841	38	0	1	54.58	11.86	55.19
104	244	852	15	1	0	54.87	11.86	55.79
104	244	901	35	1	0	55.25	11.86	56.4
111	244	1526	2	0	1	98.3	11.92	89.1
111	244	1526	4	0	1	98.3	11.91	89.2
104	244	1527	11	1	0	98.3	11.91	89.4
104	244	1528	24	1	0	98.4	11.91	89.6
111	244	1529	49	0	1	98.6	11.91	90
104	244	1539	2	1	0	99.5	11.91	90
111	244	1705	47	0	1	105.4	11.92	92.6
104	244	1707	52	1	0	105.5	11.92	92.7
111	244	1710	12	0	1	105.5	11.92	92.2
104	244	1713	56	1	0	105.4	11.92	91.9
111	244	1749	31	0	1	105.4	11.92	91.7
104	244	1757	12	1	0	105.2	11.92	90.4
111	244	1758	57	0	1	105.1	11.91	90.4
111	244	1759	8	0	1	105.2	11.9	90.3
104	244	1802	55	1	0	105	11.9	90.7
111	245	621	44	0	1	55.3	11.83	54.46
104	245	629	49	1	0	55.15	11.83	54.39
111	245	732	29	0	1	54.2	11.84	54.04
111	245	1311	6	0	1	85.8	11.86	84.4
111	245	1311	17	0	1	85.8	11.86	84.8
104	245	1313	9	1	0	86.1	11.86	84.2
111	245	1314	17	0	1	86.3	11.86	84.1
104	245	1314	28	1	0	86.3	11.86	84.3
104	245	1315	37	1	0	86.5	11.86	85.6
111	245	1651	40	0	1	111.2	11.89	98.3
104	245	1658	17	1	0	111.5	11.89	98.4
111	245	1707	53	0	1	111.6	11.89	97.7
111	245	1709	37	0	1	111.6	11.88	96.8
104	245	1710	46	1	0	111.6	11.89	97.7
104	245	1711	3	1	0	111.6	11.88	96.9
111	245	1729	56	0	1	111.4	11.89	97.1
111	245	1730	0	0	1	111.4	11.89	97.3
104	245	1733	50	1	0	111.4	11.89	97.3
104	245	1741	17	1	0	111.4	11.89	97
111	245	1843	27	0	1	105.8	11.88	91
104	245	1846	27	1	0	105.2	11.88	91.1
111	245	1932	33	0	1	97.5	11.88	85.4
104	245	1936	51	1	0	96.9	11.88	84.9
111	246	619	18	0	1	57.39	11.79	56.55

111	246	631	33	0	1	57.14	11.79	55.15
104	246	636	18	1	0	57.03	11.8	56.34
104	246	637	58	1	0	57.01	11.78	55.79
111	246	1221	10	0	1	78.8	11.81	78.8
104	246	1223	5	1	0	79	11.82	80.1
111	246	1331	7	0	1	90.1	11.84	86.5
111	246	1331	12	0	1	90.1	11.83	86.7
111	246	1331	38	0	1	90.2	11.83	87.4
104	246	1332	6	1	0	90.2	11.83	87.7
104	246	1333	12	1	0	90.4	11.83	87.3
104	246	1333	38	1	0	90.5	11.84	87
111	246	1715	2	0	1	111.3	11.86	97.6
104	246	1720	3	1	0	111.1	11.86	97.3
111	246	1734	13	0	1	111	11.86	96.3
111	246	1735	56	0	1	110.9	11.86	95.8
104	246	1738	42	1	0	110.9	11.85	95
104	246	1740	8	1	0	110.9	11.85	95.4
111	246	1841	26	0	1	105.1	11.85	90.9
111	246	1844	4	0	1	104.7	11.84	90.4
104	246	1852	4	1	0	103.3	11.86	89.3
104	246	1852	8	1	0	103.3	11.84	89.4
111	246	1852	10	0	1	103.3	11.85	89.4
111	246	2148	6	0	1	82.9	11.82	75.5
104	246	2150	55	1	0	82.6	11.82	75.4
111	247	720	38	0	1	57.31	11.75	57.23
111	247	721	34	0	1	57.33	11.75	57.25
111	247	723	1	0	1	57.33	11.77	57.56
104	247	727	27	1	0	57.38	11.76	57.46
104	247	727	41	1	0	57.36	11.75	57.51
104	247	728	3	1	0	57.4	11.75	57.48
111	247	728	5	0	1	57.38	11.76	57.46
111	247	1255	28	0	1	70	11.77	71.8
104	247	1259	0	1	0	70.7	11.77	69.96
111	247	1259	11	0	1	70.7	11.77	69.84
104	247	1303	33	1	0	71.6	11.76	71
111	247	1316	32	0	1	74.2	11.77	72.5
104	247	1318	58	1	0	74.6	11.78	74.5
111	247	1319	1	0	1	74.6	11.78	74.5
111	247	1631	57	0	1	101.5	11.81	91.3
104	247	1634	14	1	0	101.8	11.8	91.4
111	247	1706	24	0	1	103.2	11.82	91.1
111	247	1711	36	0	1	103.2	11.81	90.8
104	247	1711	59	1	0	103.2	11.81	91.2
104	247	1712	6	1	0	103.2	11.8	91.1
104	247	1716	57	1	0	103.1	11.8	91
111	247	1841	47	0	1	98.3	11.8	84.9
104	247	1843	54	1	0	97.9	11.8	85.2
111	248	637	23	0	1	56.5	11.74	56.81
111	248	638	16	0	1	56.48	11.73	56.79
111	248	638	17	0	1	56.5	11.72	56.73
104	248	640	20	1	0	56.48	11.71	56.79
104	248	640	25	1	0	56.48	11.72	56.79
104	248	640	30	2	0	56.5	11.7	56.81

104	248	644	59	1	0	56.54	11.71	56.69
111	248	1145	18	0	1	64.86	11.72	64.71
111	248	1145	48	0	1	64.88	11.72	64.66
104	248	1146	28	1	0	64.92	11.72	64.77
104	248	1151	20	1	0	65.18	11.72	65.03
111	248	1327	59	0	1	76.4	11.74	75.3
111	248	1328	3	0	1	76.4	11.73	75.3
111	248	1329	35	0	1	76.7	11.74	74.7
104	248	1335	55	1	0	77.8	11.74	75.9
104	248	1337	13	1	0	78.1	11.74	76.2
104	248	1339	20	1	0	78.6	11.74	77.4
111	248	1339	22	0	1	78.5	11.75	77.3
111	248	1452	8	0	1	90.5	11.76	84.8
104	248	1453	58	1	0	90.7	11.76	86.2
111	248	1456	24	0	1	91	11.76	86.1
104	248	1500	35	1	0	91.5	11.76	86.6
111	248	1638	33	0	1	103.9	11.77	93.6
104	248	1641	49	1	0	104.2	11.77	93.2
111	248	1723	13	0	1	105.4	11.77	93.3
111	248	1723	34	0	1	105.4	11.76	93.1
111	248	1723	50	0	1	105.4	11.78	93.6
104	248	1725	58	1	0	105.4	11.77	93
111	248	1726	1	0	1	105.4	11.78	93
104	248	1727	25	1	0	105.5	11.77	93.4
104	248	1727	29	1	0	105.4	11.76	93.5
111	248	1819	18	0	1	104.3	11.76	89.4
111	248	1819	37	0	1	104.3	11.78	89.6
104	248	1824	45	1	0	103.3	11.77	88.8
104	248	1826	9	1	0	103	11.75	88.4
111	249	721	14	0	1	55.84	11.68	55.61
111	249	1141	54	0	1	72.9	11.7	75.9
111	249	1142	12	0	1	73	11.71	75.7
111	249	1142	39	0	1	73	11.69	75.1
104	249	1143	32	1	0	73.2	11.7	75.3
104	249	1144	44	1	0	73.3	11.7	75.4
104	249	1152	34	1	0	74.5	11.69	76.1
111	249	1509	30	0	1	104	11.73	98.2
111	249	1509	50	0	1	104	11.75	98.5
104	249	1510	30	1	0	104.1	11.73	98.6
104	249	1511	24	1	0	104.2	11.74	97.6
111	249	1528	15	0	1	106.6	11.74	100.2
104	249	1534	23	1	0	107.3	11.74	100.1
111	249	1723	22	0	1	112.8	11.75	99.4
104	249	1723	28	1	0	112.8	11.75	99.4
111	249	1725	40	0	1	112.7	11.74	98.4
104	249	1728	2	1	0	112.8	11.74	97.8
104	249	1728	42	1	0	112.8	11.74	97.7
111	249	1748	5	0	1	112.3	11.74	97.3
104	249	1751	57	1	0	112.3	11.74	98.1
104	249	1807	50	1	0	112.1	11.75	96.3
111	250	626	10	0	1	60.36	11.66	59.3
104	250	626	19	1	0	60.34	11.65	59.36
104	250	626	36	1	1	60.34	11.66	59.43

111	250	626	36	0	1	60.34	11.66	59.43
111	250	627	13	0	1	60.34	11.66	59.28
104	250	631	25	1	0	60.21	11.66	59.3
104	250	631	46	1	0	60.23	11.66	59.16
104	250	637	31	1	0	60.13	11.64	59.45
111	250	637	35	0	1	60.11	11.65	59.43
111	250	654	48	0	1	59.77	11.67	59.01
111	250	747	44	0	1	59.06	11.66	58.68
104	250	749	5	1	0	59.04	11.64	58.59
111	250	749	16	0	1	59.08	11.64	58.7
111	250	749	17	0	1	59.08	11.64	58.7
104	250	755	24	1	0	59.04	11.63	58.89
111	250	755	27	0	1	59.02	11.66	58.87
111	250	1448	14	0	1	103.1	11.7	97.2
111	250	1448	28	0	1	103.2	11.69	97.4
104	250	1449	35	1	0	103.3	11.69	95.4
111	250	1450	51	0	1	103.4	11.69	95.9
104	250	1451	7	1	0	103.4	11.68	96.2
104	250	1458	6	1	0	104.1	11.69	96.4
111	250	1726	9	0	1	111.8	11.7	98.9
104	250	1730	58	1	0	111.8	11.7	97.9
111	250	1752	39	0	1	111.6	11.7	97.4
104	250	1753	19	1	0	111.6	11.69	97.5
111	250	1753	22	0	1	111.6	11.7	97.5
111	250	1845	10	0	1	104.9	11.7	91.7
104	250	1846	36	1	0	104.5	11.69	91.2
111	250	1910	36	0	1	100.9	11.7	88.5
111	250	1910	37	0	1	100.9	11.7	88.5
104	250	1913	18	1	0	100.4	11.68	87.6
111	251	614	44	0	1	60.04	11.6	58.06
104	251	614	47	1	0	60.02	11.62	58.11
104	251	620	21	1	0	59.85	11.61	57.56
111	251	706	10	0	1	58.67	11.59	57.45
104	251	707	34	1	0	58.63	11.59	57.49
111	251	827	54	0	1	58.38	11.59	58.83
104	251	836	39	1	0	58.58	11.59	59.34
111	251	1518	22	0	1	108.5	11.66	101.4
111	251	1519	27	0	1	108.7	11.65	101.5
111	251	1519	32	0	1	108.7	11.65	101.5
104	251	1520	4	1	0	108.7	11.65	100.9
104	251	1521	33	1	0	108.9	11.66	101.5
104	251	1521	38	1	0	108.9	11.65	101.5

Cows have option Changed on 256 at 1520 and on 260 at 1007
Lost Data from 251 at 1700 to 256 at 1520

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	257	633	0	0	1	57.93	11.94	58
104	257	650	36	1	0	57.93	11.94	57.85
111	257	650	41	0	1	57.91	11.95	57.83
111	257	1055	35	0	1	60.9	11.94	60.83

111	257	1221	44	0	1	64.46	11.91	64.16
111	257	1223	0	0	1	64.52	11.91	64.22
104	257	1224	34	1	0	64.54	11.91	64.09
104	257	1230	3	1	0	64.76	11.92	64.31
111	257	1546	14	0	1	81.2	11.91	77
104	257	1546	51	1	0	81.3	11.92	76.9
111	257	1547	3	0	1	81.3	11.92	77
111	257	1547	28	0	1	81.3	11.91	76.7
104	257	1548	37	1	0	81.4	11.9	76.9
111	257	1558	3	0	1	81.8	11.92	77.2
111	257	1558	7	0	1	81.8	11.92	77.4
104	257	1605	7	1	0	82.3	11.91	77.3
104	257	1612	51	1	0	82.7	11.91	77.5
111	258	1307	8	0	1	73.8	11.83	69.97
111	258	1308	24	0	1	73.8	11.82	69.84
104	258	1309	33	1	0	73.8	11.83	70
104	258	1315	15	1	0	73.9	11.83	70
111	259	623	34	0	1	49.02	11.74	47.93
104	259	633	42	1	0	48.81	11.72	47.64
111	259	641	19	0	1	48.67	11.72	48.2
111	259	1222	41	0	1	70.4	11.72	73.1
104	259	1223	59	1	0	70.6	11.72	71.4
111	259	1509	42	0	1	94.2	11.74	86.5
111	260	635	53	0	1	51.43	11.63	50.35
104	260	641	56	1	0	51.32	11.61	50.7
111	260	642	0	0	1	51.34	11.63	50.72

Cows have option Changed on 260 at 1007 and 261 at 1415

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
104	260	1207	38	1	1	84.2	11.63	76.9
111	260	1207	38	0	1	84.2	11.63	76.9
111	260	1219	49	0	1	83.7	11.6	76.5
104	260	1227	46	1	0	83.4	11.61	76.5
111	260	1227	50	0	1	83.4	11.61	76.6
111	261	217	14	0	1	47.85	11.49	45.82
104	261	225	57	1	0	47.56	11.46	46
111	261	624	24	0	1	53.3	11.45	54.99

Cows have option Changed on 261 at 1415 and 267 at 1400

Station	Julian Day	Time	Seconds	Cow Out	Cow In	Data log Temp	Batt Voltage	Outside Temp
111	262	720	11	0	1	48.98	12.88	49.22
104	262	723	38	1	0	48.98	12.88	49.37
111	262	1240	29	0	1	61.1	12.88	60.42
111	262	1246	30	0	1	61.41	12.87	60.73
104	262	1246	32	1	1	61.39	12.88	60.71
111	262	1246	32	0	1	61.39	12.88	60.71
104	262	1246	54	1	0	61.41	12.88	60.73

111	262	1246	58	0	1	61.41	12.88	60.8
111	262	1247	3	0	1	61.41	12.86	60.73
104	262	1247	34	1	0	61.41	12.87	60.81
111	262	1310	7	0	1	62.97	12.88	62.82
104	262	1318	53	1	0	63.99	12.87	62.78
111	262	1319	31	0	1	64.01	12.88	62.8
104	262	1348	15	1	0	65.3	12.87	63.48
111	262	1352	46	0	1	65.51	12.88	63.86
104	262	1357	40	1	0	65.86	12.88	63.75
111	263	41	34	0	1	48.05	12.77	44.3
111	263	620	2	0	1	43.51	12.72	42.49
104	263	625	9	1	0	43.43	12.72	42.64
111	263	2106	25	0	1	57.76	12.71	52.61
111	264	1504	29	0	1	86.4	12.65	79.4
111	264	1815	18	0	1	90.4	12.63	76.3
111	265	1240	31	0	1	67.5	12.54	69.67
104	265	1242	21	1	0	67.87	12.54	69.52
111	265	1504	10	0	1	91.6	12.56	84.3
111	266	534	58	0	1	47.01	12.46	45.05
111	266	1244	46	0	1	68.82	12.46	71
104	266	1245	58	1	0	69.1	12.46	71.4
111	266	1504	18	0	1	93.1	12.5	84.3
111	266	1533	48	0	1	96.8	12.49	86.5
104	266	1534	45	1	0	96.9	12.5	85.4
111	266	1718	47	0	1	101.5	12.5	87.8
104	266	1722	34	1	0	101.7	12.49	87.8
111	266	1746	0	0	1	100.6	12.5	85.7
104	266	1751	2	1	0	99.9	12.49	84.8
111	267	126	52	0	1	55.79	12.42	52.1
111	267	1336	53	0	1	75.2	12.43	73.2
111	267	1336	56	0	1	75.2	12.42	73.3
104	267	1338	43	1	0	75.3	12.43	73
111	267	1338	45	0	1	75.3	12.43	72.9
111	267	1338	50	0	1	75.3	12.44	72.9
111	267	1338	55	0	2	75.3	12.44	73.1
104	267	1339	10	1	0	75.3	12.42	73.5
104	267	1339	26	1	0	75.4	12.42	73.4

APPENDIX D

Table 1D. Percentage of days that rainfall exceeds critical levels for Hillsboro wet water year 1982.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	19	6	6	6	3	3	3	3	0
November	17	13	10	3	3	0	0	0	0
December	39	26	23	19	13	10	3	3	3
January	32	26	13	6	3	3	0	0	0
February	54	39	36	21	14	4	0	0	0
March	16	16	6	6	6	3	3	0	0
April	13	7	3	3	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0
July	10	3	3	3	3	3	0	0	0
August	6	6	3	3	3	3	0	0	0
September	0	0	0	0	0	0	0	0	0

Table 2D. Percentage of days that rainfall exceeds critical levels for Hillsboro wet water year 1973.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	13	6	3	3	3	0	0	0	0
November	45	40	33	23	10	10	7	7	3
December	45	35	29	26	3	0	0	0	0
January	23	23	19	19	19	6	6	6	3
February	19	18	18	4	0	0	0	0	0
March	35	19	13	10	3	0	0	0	0
April	10	10	0	0	0	0	0	0	0
May	3	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0
July	10	3	3	3	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0

Table 3D. Percentage of days that rainfall exceeds critical levels for Hillsboro dry water year 1963.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	10	6	6	3	3	0	0	0	0
November	23	20	13	7	7	0	0	0	0
December	19	13	10	10	0	0	0	0	0
January	42	29	29	26	13	6	3	0	0
February	0	0	0	0	0	0	0	0	0
March	10	10	6	3	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	10	10	7	3	0	0	0	0	0
July	3	3	3	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0
September	3	0	0	0	0	0	0	0	0

Table 4D. Percentage of days that rainfall exceeds critical levels for Hillsboro dry water year 1976.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	10	0	0	0	0	0	0	0	0
November	3	0	0	0	0	0	0	0	0
December	6	3	3	3	0	0	0	0	0
January	3	3	0	0	0	0	0	0	0
February	11	7	4	0	0	0	0	0	0
March	16	6	6	6	3	0	0	0	0
April	3	3	0	0	0	0	0	0	0
May	6	3	3	3	0	0	0	0	0
June	3	0	0	0	0	0	0	0	0
July	6	0	0	0	0	0	0	0	0
August	10	10	10	6	6	3	0	0	0
September	17	10	0	0	0	0	0	0	0

Table 5D. Percentage of days that rainfall exceeds critical levels for Scoggins Dam wet water year 1982.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	16	13	10	10	6	6	6	3	3
November	30	27	20	13	13	3	3	0	0
December	39	29	26	23	19	19	13	3	3
January	35	26	23	16	10	6	0	0	0
February	50	50	46	39	29	14	4	0	0
March	42	32	29	19	10	10	3	0	0
April	10	7	7	7	0	0	0	0	0
May	3	0	0	0	0	0	0	0	0
June	7	3	3	0	0	0	0	0	0
July	10	6	3	3	3	0	0	0	0
August	6	6	3	3	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0

Table 6D. Percentage of days that rainfall exceeds critical levels for Scoggins Dam dry water year 1976.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	3	3	3	3	0	0	0	0	0
November	7	7	3	0	0	0	0	0	0
December	10	6	3	0	0	0	0	0	0
January	3	3	0	0	0	0	0	0	0
February	14	14	11	7	4	0	0	0	0
March	19	13	13	10	3	3	0	0	0
April	0	0	0	0	0	0	0	0	0
May	6	6	6	3	0	0	0	0	0
June	7	3	3	3	0	0	0	0	0
July	3	0	0	0	0	0	0	0	0
August	6	6	6	6	6	6	3	0	0
September	13	7	3	3	3	0	0	0	0

Table 7D. Percentage of days that rainfall exceeds critical levels for Hillsboro average water year 1948 - 1991.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	12	8	6	4	2	1	0	0	0
November	23	17	13	8	5	3	2	0	0
December	25	19	15	11	5	3	2	0	0
January	24	19	15	11	6	3	2	0	0
February	19	14	10	7	3	2	1	0	0
March	16	10	7	5	2	1	0	0	0
April	7	4	3	1	0	0	0	0	0
May	6	3	2	1	0	0	0	0	0
June	6	3	2	1	0	0	0	0	0
July	2	1	1	0	0	0	0	0	0
August	3	2	2	1	1	0	0	0	0
September	6	4	3	2	1	0	0	0	0

Table 8D. Percentage of days that rainfall exceeds critical levels for Scoggings Dam average water year 1973 - 1985.

	Critical Rainfall Levels								
Month	0.29	0.39	0.48	0.61	0.83	1.05	1.30	1.71	2.03
October	15	12	9	5	2	2	1	0	0
November	34	28	23	17	11	6	4	0	0
December	30	24	22	18	13	10	6	0	0
January	21	17	15	12	6	4	3	0	0
February	33	27	21	15	10	6	2	0	0
March	23	17	13	8	3	2	1	0	0
April	12	9	6	4	1	1	0	0	0
May	6	4	3	2	1	1	1	0	0
June	6	4	2	1	0	0	0	0	0
July	2	1	1	1	0	0	0	0	0
August	5	3	2	2	1	1	0	0	0
September	8	4	3	3	2	1	1	0	0

Table 9D. Percentage of days that rainfall produces runoff from different land uses for Hillsboro wet water year 1982.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	6	6	3	6	3	3
November	17	3	3	3	3	3
December	39	26	19	19	19	13
January	32	26	6	6	6	3
February	54	39	21	21	21	14
March	16	16	6	6	6	3
April	7	3	0	3	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	3	3	0	3	3	0
August	3	3	0	3	3	0
September	0	0	0	0	0	0

Table 10D. Percentage of days that rainfall produces runoff from different land uses for Hillsboro wet water year 1973.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	6	3	0	3	3	0
November	45	23	10	23	10	10
December	45	35	26	26	3	3
January	23	23	19	19	19	19
February	19	18	4	4	0	0
March	35	19	10	10	3	0
April	10	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	3	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0

Table 11D. Percentage of days that rainfall produces runoff from different land uses for Hillsboro dry water year 1963.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	6	3	0	3	3	0
November	23	7	7	7	7	7
December	19	13	10	10	10	0
January	42	29	26	26	26	13
February	0	0	0	0	0	0
March	10	10	3	3	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	7	0	0	0	0	0
July	3	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0

Table 12D. Percentage of days that rainfall produces runoff from different land uses for Hillsboro dry water year 1976.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	0	0	0	0	0	0
November	3	0	0	0	0	0
December	6	3	3	3	3	0
January	3	3	0	0	0	0
February	11	7	0	0	0	0
March	16	6	6	6	3	0
April	3	0	0	0	0	0
May	3	3	0	3	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	10	6	0	6	6	0
September	0	0	0	0	0	0

Table 13D. Percentage of days that rainfall produces runoff from different land uses for Scoggins Dam wet water year 1982.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	13	10	6	10	6	6
November	30	13	13	13	13	13
December	39	29	23	23	23	19
January	35	26	16	16	16	10
February	50	50	39	39	39	29
March	42	32	19	19	10	10
April	7	7	0	7	0	0
May	0	0	0	0	0	0
June	3	0	0	0	0	0
July	3	3	0	3	0	0
August	3	0	0	0	0	0
September	0	0	0	0	0	0

Table 14D. Percentage of days that rainfall produces runoff from different land uses for Scoggins Dam dry water year 1976.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	3	3	0	3	0	0
November	7	0	0	0	0	0
December	10	6	0	0	0	0
January	3	3	0	0	0	0
February	14	14	7	7	7	4
March	19	13	10	10	3	3
April	0	0	0	0	0	0
May	6	3	0	3	0	0
June	3	0	0	0	0	0
July	0	0	0	0	0	0
August	6	6	3	6	6	0
September	3	3	0	3	3	0

Table 15D. Percentage of days that rainfall produces runoff from different land uses for Hillsboro average water year 1948 - 1991.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	8	4	1	4	2	1
November	23	8	5	8	8	5
December	25	19	11	11	11	5
January	24	19	11	11	11	6
February	19	14	7	7	7	3
March	16	10	5	5	2	1
April	4	1	0	1	0	0
May	3	1	0	1	0	0
June	2	0	0	0	0	0
July	1	0	0	0	0	0
August	2	1	0	1	1	0
September	3	2	0	1	1	0

Table 16D. Percentage of days that rainfall produces runoff from different land uses for Scoggins Dam average water year 1948 - 1991.

Month	Impermeable Urban Areas	Permeable Urban Areas	Pasture	Row Crops	Small Grain	Forested
October	12	5	2	5	2	2
November	34	17	11	17	17	11
December	30	24	18	18	18	13
January	21	17	12	12	12	6
February	33	27	15	15	15	10
March	23	17	8	8	3	2
April	9	4	1	4	1	1
May	4	2	1	2	1	1
June	2	0	0	0	0	0
July	1	0	0	0	0	0
August	2	1	0	1	1	0
September	3	3	1	2	2	0

APPENDIX E

Table 1E. Analysis of the fecal coliforms and fecal streptococci entering the stream during a summer runoff event from Enterprise No. 2.

Summer conditions Die-off Rate FC & FS = .047

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	1.413E+07	7.988E+07
28	0.000E+00	0.000E+00
27	1.755E+07	9.919E+07
26	1.955E+07	1.105E+08
25	2.179E+07	1.232E+08
24	0.000E+00	0.000E+00
23	2.705E+07	1.529E+08
22	3.015E+07	1.704E+08
21	3.359E+07	1.899E+08
20	0.000E+00	0.000E+00
19	4.171E+07	2.358E+08
18	4.648E+07	2.627E+08
17	5.179E+07	2.927E+08
16	0.000E+00	0.000E+00
15	6.431E+07	3.635E+08
14	7.165E+07	4.050E+08
13	7.984E+07	4.513E+08
12	0.000E+00	0.000E+00
11	9.914E+07	5.604E+08
10	1.105E+08	6.244E+08
9	1.231E+08	6.958E+08
8	0.000E+00	0.000E+00
7	1.528E+08	8.639E+08
6	1.703E+08	9.626E+08
5	1.898E+08	1.073E+09
4	0.000E+00	0.000E+00
3	2.356E+08	1.332E+09
2	2.626E+08	1.484E+09
1	2.926E+08	1.654E+09
0	0.000E+00	0.000E+00
Sum =	2.156E+09	1.219E+10
Amount in Runoff (.3%) =	6.468E+06	3.656E+07

Rainfall amount =	1.3	inches
Runoff Depth =	0.1	inches
Area of Runoff = 25 ft x 25 ft	625	sq. ft.
Runoff Volume =	5.208	cu. ft.
or	1.475E+05	ml
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	4.386E+01	2.479E+02

Table 1E. continued.

Data for Study Site with Four Cows Die-off Rate FC & FS = .047
Summer conditions

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	3.260E+08	1.843E+09
27	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00
24	3.260E+08	1.843E+09
23	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00
20	3.260E+08	1.843E+09
19	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00
16	3.260E+08	1.843E+09
15	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00
12	3.260E+08	1.843E+09
11	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00
8	3.260E+08	1.843E+09
7	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00
4	3.260E+08	1.843E+09
3	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
1	0.000E+00	0.000E+00
0	3.260E+08	1.843E+09
Sum =	2.608E+09	1.474E+10
Amount in Stream (100%) =	2.608E+09	1.474E+10
Total Reaching Stream =	2.615E+09	1.478E+10
% Reduced Due to Alternate Water Source =	73.27%	73.27%

Table 1E. continued.

Data for Study Site with Four Cows Die-off Rate FC & FS = .047
Summer conditions

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	3.260E+08	1.843E+09
28	3.260E+08	1.843E+09
27	3.260E+08	1.843E+09
26	3.260E+08	1.843E+09
25	3.260E+08	1.843E+09
24	3.260E+08	1.843E+09
23	3.260E+08	1.843E+09
22	3.260E+08	1.843E+09
21	3.260E+08	1.843E+09
20	3.260E+08	1.843E+09
19	3.260E+08	1.843E+09
18	3.260E+08	1.843E+09
17	3.260E+08	1.843E+09
16	3.260E+08	1.843E+09
15	3.260E+08	1.843E+09
14	3.260E+08	1.843E+09
13	3.260E+08	1.843E+09
12	3.260E+08	1.843E+09
11	3.260E+08	1.843E+09
10	3.260E+08	1.843E+09
9	3.260E+08	1.843E+09
8	3.260E+08	1.843E+09
7	3.260E+08	1.843E+09
6	3.260E+08	1.843E+09
5	3.260E+08	1.843E+09
4	3.260E+08	1.843E+09
3	3.260E+08	1.843E+09
2	3.260E+08	1.843E+09
1	3.260E+08	1.843E+09
0	3.260E+08	1.843E+09
Sum =	9.781E+09	5.528E+10

Total Reaching Stream =	9.781E+09	5.528E+10

Table 2E. Analysis of the fecal coliforms and fecal streptococci entering the stream during a summer runoff event from Enterprise No. 1.

Summer conditions | Die-off Rate FC & FS = .047

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	1.035E+06	5.177E+08
27	0.000E+00	0.000E+00
26	1.285E+06	6.427E+08
25	0.000E+00	0.000E+00
24	1.596E+06	7.981E+08
23	0.000E+00	0.000E+00
22	1.982E+06	9.909E+08
21	0.000E+00	0.000E+00
20	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00
18	3.055E+06	1.528E+09
17	0.000E+00	0.000E+00
16	3.794E+06	1.897E+09
15	0.000E+00	0.000E+00
14	4.711E+06	2.355E+09
13	0.000E+00	0.000E+00
12	5.849E+06	2.924E+09
11	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00
8	9.017E+06	4.509E+09
7	0.000E+00	0.000E+00
6	1.120E+07	5.598E+09
5	0.000E+00	0.000E+00
4	1.390E+07	6.951E+09
3	0.000E+00	0.000E+00
2	1.726E+07	8.631E+09
1	0.000E+00	0.000E+00
0	0.000E+00	0.000E+00
Sum =	7.468E+07	3.734E+10
Amount in Runoff (.2%) =	1.494E+05	7.468E+07

Rainfall amount =	1.3 inches	
Runoff Depth =	0.1 inches	
Area of Runoff = 25 ft x 25 ft	625 sq. ft.	
Runoff Volume =	5.208 cu. ft.	
or	1.475E+05 ml	
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	1.013E+00	5.064E+02

Table 2E. continued.

Data for Study Site with Two Horses   Die-off Rate FC & FS = .047
Summer conditions

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	0.000E+00	0.000E+00
27	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00
24	0.000E+00	0.000E+00
23	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00
20	2.143E+07	1.072E+10
19	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00
16	0.000E+00	0.000E+00
15	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00
12	0.000E+00	0.000E+00
11	0.000E+00	0.000E+00
10	2.143E+07	1.072E+10
9	0.000E+00	0.000E+00
8	0.000E+00	0.000E+00
7	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00
4	0.000E+00	0.000E+00
3	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
1	0.000E+00	0.000E+00
0	2.143E+07	1.072E+10
Sum =	6.430E+07	3.215E+10
Amount in Stream (100%) =	6.430E+07	3.215E+10
Total Reaching Stream =	6.445E+07	3.222E+10
% Reduced Due to Alternate Water Source =	79.95%	79.95%

Table 2E. continued.

Data for Study Site with Two Horses Die-off Rate FC & FS = .047
Summer conditions

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	2.143E+07	1.072E+10
27	0.000E+00	0.000E+00
26	2.143E+07	1.072E+10
25	0.000E+00	0.000E+00
24	2.143E+07	1.072E+10
23	0.000E+00	0.000E+00
22	2.143E+07	1.072E+10
21	0.000E+00	0.000E+00
20	2.143E+07	1.072E+10
19	0.000E+00	0.000E+00
18	2.143E+07	1.072E+10
17	0.000E+00	0.000E+00
16	2.143E+07	1.072E+10
15	0.000E+00	0.000E+00
14	2.143E+07	1.072E+10
13	0.000E+00	0.000E+00
12	2.143E+07	1.072E+10
11	0.000E+00	0.000E+00
10	2.143E+07	1.072E+10
9	0.000E+00	0.000E+00
8	2.143E+07	1.072E+10
7	0.000E+00	0.000E+00
6	2.143E+07	1.072E+10
5	0.000E+00	0.000E+00
4	2.143E+07	1.072E+10
3	0.000E+00	0.000E+00
2	2.143E+07	1.072E+10
1	0.000E+00	0.000E+00
0	2.143E+07	1.072E+10
Sum =	3.215E+08	1.607E+11

Total Reaching Stream = 3.215E+08 1.607E+11

Table 3E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.61 inch) every four days from Enterprise No. 2.

Winter conditions, Rain every fourth day   Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	3.092E+08	1.748E+09
28	0.000E+00	0.000E+00
27	2.781E+08	1.572E+09
26	2.933E+08	1.658E+09
25	3.092E+08	1.748E+09
24	0.000E+00	0.000E+00
23	2.781E+08	1.572E+09
22	2.933E+08	1.658E+09
21	3.092E+08	1.748E+09
20	0.000E+00	0.000E+00
19	2.781E+08	1.572E+09
18	2.933E+08	1.658E+09
17	3.092E+08	1.748E+09
16	0.000E+00	0.000E+00
15	2.781E+08	1.572E+09
14	2.933E+08	1.658E+09
13	3.092E+08	1.748E+09
12	0.000E+00	0.000E+00
11	2.781E+08	1.572E+09
10	2.933E+08	1.658E+09
9	3.092E+08	1.748E+09
8	0.000E+00	0.000E+00
7	2.781E+08	1.572E+09
6	2.933E+08	1.658E+09
5	3.092E+08	1.748E+09
4	0.000E+00	0.000E+00
3	2.781E+08	1.572E+09
2	2.933E+08	1.658E+09
1	3.092E+08	1.748E+09
0	0.000E+00	0.000E+00
Sum =	6.473E+09	3.659E+10
Amount in Runoff (2%) =	1.295E+08	7.318E+08

Rainfall amount =	0.61	inches
Runoff Depth =	0.1	inches
Area of Runoff = 25 ft x 25 ft =	625	sq. ft.
Runoff Volume =	41.664	cu. ft.
or	1.180E+06	ml
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	1.097E+02	6.202E+02

Table 3E. continued

Data for Study Site with Four Cows   Die-off Rate FC & FS = .023
Winter conditions, Rain every fourth day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	3.260E+08	1.843E+09
27	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00
24	3.260E+08	1.843E+09
23	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00
20	3.260E+08	1.843E+09
19	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00
16	3.260E+08	1.843E+09
15	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00
12	3.260E+08	1.843E+09
11	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00
8	3.260E+08	1.843E+09
7	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00
4	3.260E+08	1.843E+09
3	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
1	0.000E+00	0.000E+00
0	3.260E+08	1.843E+09

Sum =	2.608E+09	1.474E+10
Amount in Stream (100%) =	2.608E+09	1.474E+10
Total Reaching Stream =	2.738E+09	1.547E+10
% Reduced Due to Alternate Water Source =	72.01%	72.01%

Table 3E. continued

Data for Study Site with Four Cows   Die-off Rate FC & FS = .023
Winter conditions, Rain every fourth day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	3.260E+08	1.843E+09
28	3.260E+08	1.843E+09
27	3.260E+08	1.843E+09
26	3.260E+08	1.843E+09
25	3.260E+08	1.843E+09
24	3.260E+08	1.843E+09
23	3.260E+08	1.843E+09
22	3.260E+08	1.843E+09
21	3.260E+08	1.843E+09
20	3.260E+08	1.843E+09
19	3.260E+08	1.843E+09
18	3.260E+08	1.843E+09
17	3.260E+08	1.843E+09
16	3.260E+08	1.843E+09
15	3.260E+08	1.843E+09
14	3.260E+08	1.843E+09
13	3.260E+08	1.843E+09
12	3.260E+08	1.843E+09
11	3.260E+08	1.843E+09
10	3.260E+08	1.843E+09
9	3.260E+08	1.843E+09
8	3.260E+08	1.843E+09
7	3.260E+08	1.843E+09
6	3.260E+08	1.843E+09
5	3.260E+08	1.843E+09
4	3.260E+08	1.843E+09
3	3.260E+08	1.843E+09
2	3.260E+08	1.843E+09
1	3.260E+08	1.843E+09
0	3.260E+08	1.843E+09
Sum =	9.781E+09	5.528E+10

Total Reaching Stream =	9.781E+09	5.528E+10

Table 4E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.61 inch) every four days from Enterprise No. 1.

Winter conditions, Rain every four days   Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	2.143E+07	1.072E+10
27	0.000E+00	0.000E+00
26	1.928E+07	9.639E+09
25	0.000E+00	0.000E+00
24	2.143E+07	1.072E+10
23	0.000E+00	0.000E+00
22	1.928E+07	9.639E+09
21	0.000E+00	0.000E+00
20	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00
18	1.928E+07	9.639E+09
17	0.000E+00	0.000E+00
16	2.143E+07	1.072E+10
15	0.000E+00	0.000E+00
14	1.928E+07	9.639E+09
13	0.000E+00	0.000E+00
12	2.143E+07	1.072E+10
11	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00
8	2.143E+07	1.072E+10
7	0.000E+00	0.000E+00
6	1.928E+07	9.639E+09
5	0.000E+00	0.000E+00
4	2.143E+07	1.072E+10
3	0.000E+00	0.000E+00
2	1.928E+07	9.639E+09
1	0.000E+00	0.000E+00
0	0.000E+00	0.000E+00
Sum =	2.443E+08	1.221E+11
Amount in Runoff (2%) =	4.885E+06	2.443E+09

Rainfall amount =	0.61	inches
Runoff Depth =	0.1	inches
Area of Runoff = 25 ft x 25 ft =	625	sq. ft.
Runoff Volume =	41.664	cu. ft.
or	1.180E+06	ml
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	4.141E+00	2.070E+03

Table 4E. continued

Data for Study Site with Two Horses Die-off Rate FC & FS = .023
Winter conditions, Rain every four days

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	0.000E+00	0.000E+00
27	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00
24	0.000E+00	0.000E+00
23	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00
20	2.143E+07	1.072E+10
19	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00
16	0.000E+00	0.000E+00
15	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00
12	0.000E+00	0.000E+00
11	0.000E+00	0.000E+00
10	2.143E+07	1.072E+10
9	0.000E+00	0.000E+00
8	0.000E+00	0.000E+00
7	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00
4	0.000E+00	0.000E+00
3	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
1	0.000E+00	0.000E+00
0	2.143E+07	1.072E+10
Sum =	6.430E+07	3.215E+10
Amount in Stream (100%) =	6.430E+07	3.215E+10
Total Reaching Stream =	6.918E+07	3.459E+10
% Reduced Due to Alternate Water Source =	78.48%	78.48%

Table 4E. continued

Data for Study Site with Two Horses Die-off Rate FC & FS = .023
Winter conditions, Rain every four days

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	2.143E+07	1.072E+10
27	0.000E+00	0.000E+00
26	2.143E+07	1.072E+10
25	0.000E+00	0.000E+00
24	2.143E+07	1.072E+10
23	0.000E+00	0.000E+00
22	2.143E+07	1.072E+10
21	0.000E+00	0.000E+00
20	2.143E+07	1.072E+10
19	0.000E+00	0.000E+00
18	2.143E+07	1.072E+10
17	0.000E+00	0.000E+00
16	2.143E+07	1.072E+10
15	0.000E+00	0.000E+00
14	2.143E+07	1.072E+10
13	0.000E+00	0.000E+00
12	2.143E+07	1.072E+10
11	0.000E+00	0.000E+00
10	2.143E+07	1.072E+10
9	0.000E+00	0.000E+00
8	2.143E+07	1.072E+10
7	0.000E+00	0.000E+00
6	2.143E+07	1.072E+10
5	0.000E+00	0.000E+00
4	2.143E+07	1.072E+10
3	0.000E+00	0.000E+00
2	2.143E+07	1.072E+10
1	0.000E+00	0.000E+00
0	2.143E+07	1.072E+10
Sum =	3.215E+08	1.607E+11

Total Reaching Stream = 3.215E+08 1.607E+11

Table 5E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.61 inch) every day from Enterprise No. 2.

Winter conditions, Rain every day . Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	3.260E+08	1.843E+09
28	0.000E+00	0.000E+00
27	3.260E+08	1.843E+09
26	3.260E+08	1.843E+09
25	3.260E+08	1.843E+09
24	0.000E+00	0.000E+00
23	3.260E+08	1.843E+09
22	3.260E+08	1.843E+09
21	3.260E+08	1.843E+09
20	0.000E+00	0.000E+00
19	3.260E+08	1.843E+09
18	3.260E+08	1.843E+09
17	3.260E+08	1.843E+09
16	0.000E+00	0.000E+00
15	3.260E+08	1.843E+09
14	3.260E+08	1.843E+09
13	3.260E+08	1.843E+09
12	0.000E+00	0.000E+00
11	3.260E+08	1.843E+09
10	3.260E+08	1.843E+09
9	3.260E+08	1.843E+09
8	0.000E+00	0.000E+00
7	3.260E+08	1.843E+09
6	3.260E+08	1.843E+09
5	3.260E+08	1.843E+09
4	0.000E+00	0.000E+00
3	3.260E+08	1.843E+09
2	3.260E+08	1.843E+09
1	3.260E+08	1.843E+09
0	0.000E+00	0.000E+00
Sum =	7.172E+09	4.054E+10
Amount in Runoff (25%) =	1.793E+09	1.013E+10

Rainfall amount =	0.61	inches
Runoff Depth =	0.1	inches
Area of Runoff = 25 ft x 25 ft	625	sq. ft.
Runoff Volume =	156.24	cu. ft.
or	4.425E+06	ml
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	4.053E+02	2.291E+03

Table 5E. continued.

Data for Study Site with Four Cows Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	3.260E+08	1.843E+09
27	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00
24	3.260E+08	1.843E+09
23	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00
20	3.260E+08	1.843E+09
19	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00
16	3.260E+08	1.843E+09
15	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00
12	3.260E+08	1.843E+09
11	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00
8	3.260E+08	1.843E+09
7	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00
4	3.260E+08	1.843E+09
3	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
1	0.000E+00	0.000E+00
0	3.260E+08	1.843E+09
Sum =	2.608E+09	1.474E+10
Amount in Stream (100%)	2.608E+09	1.474E+10
Total Reaching Stream =	4.401E+09	2.488E+10
% Reduced Due to Alternate Water Source	55.00%	55.00%

Table 5E. continued.

Data for Study Site with Four Cows   Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	3.260E+08	1.843E+09
28	3.260E+08	1.843E+09
27	3.260E+08	1.843E+09
26	3.260E+08	1.843E+09
25	3.260E+08	1.843E+09
24	3.260E+08	1.843E+09
23	3.260E+08	1.843E+09
22	3.260E+08	1.843E+09
21	3.260E+08	1.843E+09
20	3.260E+08	1.843E+09
19	3.260E+08	1.843E+09
18	3.260E+08	1.843E+09
17	3.260E+08	1.843E+09
16	3.260E+08	1.843E+09
15	3.260E+08	1.843E+09
14	3.260E+08	1.843E+09
13	3.260E+08	1.843E+09
12	3.260E+08	1.843E+09
11	3.260E+08	1.843E+09
10	3.260E+08	1.843E+09
9	3.260E+08	1.843E+09
8	3.260E+08	1.843E+09
7	3.260E+08	1.843E+09
6	3.260E+08	1.843E+09
5	3.260E+08	1.843E+09
4	3.260E+08	1.843E+09
3	3.260E+08	1.843E+09
2	3.260E+08	1.843E+09
1	3.260E+08	1.843E+09
0	3.260E+08	1.843E+09
Sum =	9.781E+09	5.528E+10

Total Reaching Stream = 9.781E+09 5.528E+10

Table 6E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.61 inch) every day from Enterprise No. 1.

Winter conditions, Rain every day Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	2.143E+07	1.072E+10
27	0.000E+00	0.000E+00
26	2.143E+07	1.072E+10
25	0.000E+00	0.000E+00
24	2.143E+07	1.072E+10
23	0.000E+00	0.000E+00
22	2.143E+07	1.072E+10
21	0.000E+00	0.000E+00
20	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00
18	2.143E+07	1.072E+10
17	0.000E+00	0.000E+00
16	2.143E+07	1.072E+10
15	0.000E+00	0.000E+00
14	2.143E+07	1.072E+10
13	0.000E+00	0.000E+00
12	2.143E+07	1.072E+10
11	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00
8	2.143E+07	1.072E+10
7	0.000E+00	0.000E+00
6	2.143E+07	1.072E+10
5	0.000E+00	0.000E+00
4	2.143E+07	1.072E+10
3	0.000E+00	0.000E+00
2	2.143E+07	1.072E+10
1	0.000E+00	0.000E+00
0	0.000E+00	0.000E+00
Sum =	2.572E+08	1.286E+11
Amount in Runoff (25%) =	6.430E+07	3.215E+10

Rainfall amount =	0.61	inches
Runoff Depth =	0.1	inches
Area of Runoff = 25 ft x 25 ft	625	sq. ft.
Runoff Volume =	156.24	cu. ft.
or	4.425E+06	ml
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	1.453E+01	7.266E+03

Table 6E. continued.

Data for Study Site with Two Horses   Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	0.000E+00	0.000E+00
27	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00
24	0.000E+00	0.000E+00
23	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00
20	2.143E+07	1.072E+10
19	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00
16	0.000E+00	0.000E+00
15	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00
12	0.000E+00	0.000E+00
11	0.000E+00	0.000E+00
10	2.143E+07	1.072E+10
9	0.000E+00	0.000E+00
8	0.000E+00	0.000E+00
7	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00
4	0.000E+00	0.000E+00
3	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00
1	0.000E+00	0.000E+00
0	2.143E+07	1.072E+10
Sum =	6.430E+07	3.215E+10
Amount in Stream (100%)	6.430E+07	3.215E+10
Total Reaching Stream =	1.286E+08	6.430E+10
% Reduced Due to Alternate Water Source	60.00%	60.00%

Table 6E. continued.

Data for Study Site with Two Horses Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

Day	Bacteria (FC)	Bacteria (FS)
29	0.000E+00	0.000E+00
28	2.143E+07	1.072E+10
27	0.000E+00	0.000E+00
26	2.143E+07	1.072E+10
25	0.000E+00	0.000E+00
24	2.143E+07	1.072E+10
23	0.000E+00	0.000E+00
22	2.143E+07	1.072E+10
21	0.000E+00	0.000E+00
20	2.143E+07	1.072E+10
19	0.000E+00	0.000E+00
18	2.143E+07	1.072E+10
17	0.000E+00	0.000E+00
16	2.143E+07	1.072E+10
15	0.000E+00	0.000E+00
14	2.143E+07	1.072E+10
13	0.000E+00	0.000E+00
12	2.143E+07	1.072E+10
11	0.000E+00	0.000E+00
10	2.143E+07	1.072E+10
9	0.000E+00	0.000E+00
8	2.143E+07	1.072E+10
7	0.000E+00	0.000E+00
6	2.143E+07	1.072E+10
5	0.000E+00	0.000E+00
4	2.143E+07	1.072E+10
3	0.000E+00	0.000E+00
2	2.143E+07	1.072E+10
1	0.000E+00	0.000E+00
0	2.143E+07	1.072E+10
Sum =	3.215E+08	1.607E+11

Total Reaching Stream = 3.215E+08 1.607E+11

Table 7E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.89 inch) every four days from Enterprise No. 2.

Winter conditions, Rain every fourth day   Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	6.473E+09	3.659E+10
	6.473E+08	3.659E+09
	0.89	inches
	0.25	inches
	625	sq. ft.
	104.167	cu. ft.
	2.950E+06	ml
	Fecal Col.	Fecal Strep.
per ml =	2.195E+02	1.240E+03

Table 8E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.89 inch) every four days from Enterprise No. 1.

Winter conditions, Rain every fourth day   Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	2.443E+08	1.221E+11
	2.443E+07	1.221E+10
	0.89	inches
	0.25	inches
	625	sq. ft.
	104.167	cu. ft.
	2.950E+06	ml
	Fecal Col.	Fecal Strep.
per ml =	8.281E+00	4.141E+03

Table 7E. continued.

Data for Study Site with Four Cows Die-off Rate FC & FS = .023
Winter conditions, Rain every fourth day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	2.608E+09	1.474E+10
Amount in Stream (100%) =	2.608E+09	1.474E+10
Total Reaching Stream =	3.255E+09	1.840E+10
% Reduced Due to Alternate Water Source =	66.71%	66.71%

Table 8E. continued.

Data for Study Site with Two Horses Die-off Rate FC & FS = .023
Winter conditions, Rain every fourth day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	6.430E+07	3.215E+10
Amount in Stream (100%) =	6.430E+07	3.215E+10
Total Reaching Stream =	8.872E+07	4.436E+10
% Reduced Due to Alternate Water Source =	72.40%	72.40%

Table 7E. continued.

Data for Study Site with Four Cows Die-off Rate FC & FS = .023
Winter conditions, Rain every fourth day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	9.781E+09	5.528E+10
Total Reaching Stream =	9.781E+09	5.528E+10

Table 8E. continued.

Data for Study Site with Two Horses Die-off Rate FC & FS = .023
Winter conditions, Rain every fourth day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	3.215E+08	1.607E+11
Total Reaching Stream =	3.215E+08	1.607E+11

Table 9E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.89 inch) every day from Enterprise No. 2.

Winter conditions, Rain every day — Die-off Rate FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	7.172E+09	4.054E+10
Amount in Runoff (50%) =	3.586E+09	2.027E+10
Rainfall amount =	0.89 inches	
Runoff Depth =	0.25 inches	
Area of Runoff = 25 ft x 25 ft =	625 sq. ft.	
Runoff Volume =	390.625 cu. ft.	
or	1.106E+07 ml	
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	3.242E+02	1.833E+03

Table 10E. Analysis of the fecal coliforms and fecal streptococci entering the stream during winter rain (0.89 inch) every day from Enterprise No. 1.

Winter conditions, Rain every day — FC & FS = .023

Amount of FC and FS Accumulated
Around Alternate Water Source (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	2.572E+08	1.286E+11
	1.286E+08	6.430E+10
	0.89 inches	
Runoff Depth =	0.25 inches	
Area of Runoff = 25 ft x 25 ft =	625 sq. ft.	
Runoff Volume =	390.625 cu. ft.	
or	1.106E+07 ml	
Runoff Concentration	Fecal Col.	Fecal Strep.
per ml =	1.163E+01	5.813E+03

Table 9E. continued.

Data for Study Site with Four Cows — Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	2.608E+09	1.474E+10
Amount in Stream (100%) =	2.608E+09	1.474E+10
Total Reaching Stream =	6.194E+09	3.501E+10
% Reduced Due to Alternate Water Source =	36.67%	36.67%

Table 10E. continued.

Data for Study Site with Two Horses — Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	6.430E+07	3.215E+10
Amount in Stream (100%) =	6.430E+07	3.215E+10
Total Reaching Stream =	1.929E+08	9.645E+10
% Reduced Due to Alternate Water Source =	40.00%	40.00%

Table 9E. continued.

Data for Study Site with Two Cows   Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	9.781E+09	5.528E+10
Total Reaching Stream =	9.781E+09	5.528E+10

Table 10E. continued.

Data for Study Site with Two Horses   Die-off Rate FC & FS = .023
Winter conditions, Rain every day

Amount of FC and FS Directly Deposited
in Stream with No Alternate Water Source Available (30 days)

	Bacteria (FC)	Bacteria (FS)
Sum =	3.215E+08	1.607E+11
Total Reaching Stream =	3.215E+08	1.607E+11