



# **NUTRIENT MANAGEMENT PLANNING GUIDANCE for Small Coastal Dairies**

DEVELOPED BY THE GOLD RIDGE RESOURCE CONSERVATION DISTRICT

*June 2010*

## ACKNOWLEDGEMENTS

Production of this document was made possible by grants from the State Water Resources Control Board, the North Coast Regional Water Quality Control Board, and the State Coastal Conservancy.

The Gold Ridge Resource Conservation District (RCD) wishes to thank those who authored, reviewed, and provided technical assistance on this important project. With special thanks to each of the dairy operators in the Estero Americano Watershed who partnered with us on this project. We thank them for their patience and encouragement, and for sharing their knowledge, trust, and expertise with us.

*Principal Authors:*       **Patricia Hickey**, Agricultural Program Director 2005-2009, Gold Ridge RCD  
                                  **Garry Mahrt**, Agricultural and Range Management Consultant  
                                  **Brittany Heck**, Project Manager, Gold Ridge RCD  
                                  **John Green**, Lead Scientist, Gold Ridge RCD

*Reviewers/ Editors:*     **Sierra Cantor**, Watershed Biologist, Gold Ridge RCD  
                                  **Leslie Corp**, Field Representative, Western United Dairymen  
                                  **Jeffrey Creque**, Ph.D., Agricultural Ecologist  
                                  **Lisa Hulette**, Executive Director, Gold Ridge RCD  
                                  **Noelle Johnson**, Conservation Planner, Gold Ridge RCD  
                                  **David Lewis**, Watershed Management Advisor, University of California Cooperative Extension  
                                  **Paul Martin**, Director of Environmental Services, Western United Dairymen

*Technical Assistance:*   **Lisa Bush**, Agricultural and Range Management Consultant  
                                  **Donna Chambers**, Executive Director, Humboldt County RCD  
                                  **Brooke Cole**, Engineer, USDA Natural Resources Conservation Service, Petaluma Field Office  
                                  **Charlette Epifanio**, District Conservationist, USDA Natural Resources Conservation Service, Petaluma Field Office  
                                  **Lee Erickson**, Ph.D., Agricultural Engineer  
                                  **Dayna Ghirardelli**, Clover Stornetta Farms, Inc.  
                                  **Chester Gin**, Technician, USDA Natural Resources Conservation Service, Petaluma Field Office  
                                  **Mike Griffin**, Director of Special Projects, Clover Stornetta Farms, Inc.  
                                  **Liz Hilkert**, Agricultural Engineer, USDA Natural Resources Conservation Service, Dixon Service Center  
                                  **Kevin Maloney**, Agricultural Consultant  
                                  **DeAnne Meyer**, Ph.D Livestock Waste Management Specialist, University of California  
                                  **Pacific Watershed Associates**: Rural Ranch Roads  
                                  **Joe Pozzi**, District Manager, Gold Ridge RCD

*Graphic Design:*       **Kim Dow**, DowHouse

---

# TABLE OF CONTENTS

<i>Chapter 1</i>	<b>INTRODUCTION</b> .....	1
	Glimpsing the Regulatory Future: USDA and EPA’s Unified National AFO Strategy .....	2
	Changing Practices in the North Coast Region .....	3
	The Estero Americano Watershed Dairy Enhancement Program .....	3
	Organization of the Handbook .....	4
<i>Chapter 2</i>	<b>ACHIEVING NUTRIENT BALANCE</b> .....	5
	Nutrient Concentration on Dairies .....	5
	Nutrient Balancing .....	6
	Best Management Strategies and Practices for Achieving On-Farm Nutrient Balance .....	6
	<i>Group and feed animals based on their nutrient requirements</i> .....	7
	<i>Balance Ration Protein (N) and P to 2001 NRC Guidelines</i> .....	7
	<i>Limit the Use of High-Phosphorus By-product Feeds</i> .....	7
	<i>Increase homegrown forages in rations</i> .....	8
	<i>Tips for Increasing Forage Quality: Composting Manure.</i> .....	8
<i>Chapter 3</i>	<b>NUTRIENT MANAGEMENT PLANNING</b> .....	11
	Basic Components of a Nutrient Management Plan .....	12
	Understanding Basic Soil Characteristics .....	12
	Soil Nutrient Reserves .....	13
	Dairy Manure as a Source of Fertilizer .....	13

*Organic and Inorganic Nutrients in Dairy Manure* . . . . . 13

*N-P-K Concentrations in Manure* . . . . . 14

Liquid versus Solid Manure . . . . . 14

Apply Liquid Manure Appropriately: Small, frequent, and seasonally appropriate applications . . . . . 15

To Avoid Phosphorous Build-up in Soils, Separate Solids . . . . . 15

The Nitrogen Fraction of Manure . . . . . 15

The Phosphorus Fraction of Manure . . . . . 16

The Potassium Fraction of Manure . . . . . 16

Manure Production Rates and Characteristics . . . . . 16

Matching Nutrient Applications to Crop and Site Potential . . . . . 17

*Mechanically Harvested Forage Versus Cow Harvested Forage* . . . . . 17

*Site Potential* . . . . . 18

*Plant Nutrient Requirements* . . . . . 18

Basic Guidelines for Land Application of Manure . . . . . 19

*Pre-Plan Manure Application* . . . . . 19

*Reduce Nutrient Losses and Runoff Potential* . . . . . 20

*Application Rates* . . . . . 20

*Which Manure Where?* . . . . . 20

*Chapter 4*

**BEST MANAGEMENT PRACTICES TO REDUCE NUTRIENT, PATHOGEN AND SEDIMENT POLLUTION IN RUNOFF FROM DAIRY FACILITIES AND FARM FIELDS** . . . . . 21

Pollutants of Concern and Their Delivery . . . . . 21

Pollutant Concentrations . . . . . 22

Pollutant Pathways . . . . . 22

Nutrients (Nitrogen and Phosphorus) . . . . . 22

<i>BMPs to reduce phosphorus loading to surface waters</i> .....	22
<i>BMPs to control nitrogen pollution</i> .....	23
Pathogens (bacteria, protozoa, viruses) .....	23
<i>BMPs designed to prevent pathogens from entering surface water</i> .....	23
Sediment .....	23
<i>Rill Erosion</i> .....	24
<i>Sheet Erosion</i> .....	24
<i>Gully Erosion</i> .....	24
Basic Guidelines for Assessing Grazing Impacts to Pastures .....	25
<i>Assessing Pasture Conditions</i> .....	25
<i>Assessing Seasonal Drainages and Stream Corridors</i> .....	26
<i>Assessing Ranch Roads and Animal Trails</i> .....	27
BMPs for Controlling Stormwater Runoff and Minimizing Pollutant Loads in and Around Dairy Facilities and Production Areas .....	27
<i>Minimize the amount of runoff you are managing by installing clean water diversions in and around dairy facilities and production areas</i> .....	28
<i>Identify least cost management options for reducing the concentrations of pollutants in stormwater runoff</i> .....	28
<i>Keep manure stockpiles protected from rain and surface water runoff</i> .....	28
<i>Control runoff from slabs</i> .....	28
<i>Winterize open lots</i> .....	29
<i>Install vegetated filter strips around facilities and manure storage areas, downslope of open lots, at the boundaries of silage fields or pastures receiving land applications of manure, and along drainages and streams to help filter pollutants</i> .....	29
BMPs for Grazing Sensitive Areas .....	30
<i>Riparian Pastures</i> .....	30
<i>Hillside Pastures</i> .....	31

	BMPs for Reducing Erosion from Ranch Roads .....	31
	<i>Outsloping, rolling dips and ditch relief culverts</i> .....	32
	<i>Stream crossing culverts and other structures</i> .....	34
	<i>Road surfacing</i> .....	34
	<i>Road maintenance</i> .....	34
<i>References</i>	.....	35
<i>Appendices</i>		
	Appendix A. Soil Sampling Guidelines .....	39
	Appendix B. Manure Sampling Guidelines .....	43
	Appendix C. Understanding Your Soil Report .....	45
	Appendix D. Understanding Your Manure Report .....	51
	Appendix E. Useful Conversions .....	55
	Appendix F. Residual Dry Matter .....	57
	Appendix G. Manure Production .....	59

## CHAPTER 1

# INTRODUCTION

Small, pasture-based dairy farms along the north coast of California face a unique set of management challenges both economically and environmentally. In recent years, stricter water quality standards, rising energy and feed costs, and a shift to organic dairy farming have all converged to increase demand for more intensive management of silage fields and pastures. Throughout the country, there is a clear trend towards developing more sustainable agricultural production systems. The concept of comprehensive nutrient management planning has developed over the last decade to provide dairy operators with clear definitions and technical guidance on ways to optimize the value of manure nutrients, while at the same time reducing potential nutrient losses to the environment in stormwater runoff and leaching to groundwater.

According to the USDA Natural Resources Conservation Service (USDA NRCS), the purposes of a nutrient management plan are:

- To adequately supply nutrients for plant production.
- To properly utilize manure or organic by-products as a plant nutrient source.

- To prevent agricultural non-point source pollutants such as pathogens and nutrients from entering surface and ground water resources.
- To maintain or improve soil quality.

Although dairy operators in northern California have made great strides over the last few decades in complying with minimum statewide water quality standards and regulations, agricultural non-point source pollution entering streams and coastal bays continues to impact water quality, aquatic habitat, and other commercial uses of these shared water resources. Until recently, recommended best management practices (BMPs) for dairy farmers in the North Coast Region have focused on protecting surface water quality through adequate manure storage capacity and controlling stormwater runoff in and around dairy facilities.

Less attention has been paid to land application of manure and runoff from farm fields. In many states throughout the country, including in some regions of California, dairy farmers are now required to quantify the amount of nutrients applied to farm fields, and to limit application rates based on crop nutrient requirements. For example, in the Central Valley of California, there is now a limit on the application of nitrogen to farm



Cows grazing off harvested silage field in August 2008.

fields, which may not exceed 1.65% of plant nutrient requirements. In addition, grazing operations throughout California, including dairies, are under increasing pressure to adopt pasture management practices that prevent pathogens, nutrients, and sediment from entering drainages, streams, and coastal bays.

#### **GLIMPING THE REGULATORY FUTURE: USDA AND EPA'S UNIFIED NATIONAL AFO STRATEGY**

To minimize water quality and public health impacts from animal feeding operations (AFOs) and land application of manure, the US Department of Agriculture (USDA) and the US Environmental Protection Agency (EPA) have agreed on a Unified National Strategy to encourage all AFO owners and operators to develop and implement technically sound and economically feasible site-specific Comprehensive Nutrient Management Plans (CNMPs). This national strategy is being implemented at the state

level through both regulatory and voluntary programs. A CNMP is comprised of the following components:

- **Feed management:** Adjusting animal diets and feed to reduce the amounts of nutrients in manure.
- **Manure handling and storage:** Handling and storage of manure to prevent water pollution.
- **Land application of manure:** Applying manure in ways that minimize water quality and public health risks.
- **Land management:** Utilizing conservation practices in managing crop production and pastures to minimize movement of soil, organic materials, nutrients, and pathogens from lands where manure is applied to both surface and groundwater.
- **Recording keeping:** Documenting how much manure is produced and how it will be utilized, including where, when, and the amount of nutrients applied.
- **Other utilization options:** Identifying alternative uses of manure such as composting and off-farm sales in locations where the potential for environmentally sound land application is limited.

Under the Unified National Strategy, the federal government is recommending that States adopt a *regulatory approach* for certain high risk AFOs through National Pollutant Discharge Elimination System (NPDES) permits. AFOs that meet specified criteria in the NPDES regulations are referred to as concentrated animal feeding operations or CAFOs. As part of the national strategy, NPDES permits will require CAFOs to develop CNMPs and meet other conditions to minimize the threat to water quality and public health. Three categories of CAFOs are considered priorities for the regulatory approach:

- Large facilities with greater than 1,000 animal units.



- Facilities with a high likelihood of discharging manure to water bodies, particularly where drainages or streams flow through facilities.
- A facility that is significantly contributing to water quality degradation or that is located in a watershed undergoing a Total Maximum Daily Load (TMDL) study.

In California, the State Water Resources Control Board (SWRCB) is responsible for implementing federal and state mandated water quality protection efforts. SWRCB mandates are then administered through nine Regional Water Quality Control Boards. AFO owners and operators in northern California are under the jurisdiction of either the San Francisco Regional Water Quality Control Board (Region 2) or the North Coast Regional Water Quality Control Board (Region 1). For the vast majority of AFOs in northern California, voluntary efforts will be the principal approach to assist owners and operators in developing and implementing CNMPs. While they are not currently mandated under regional Waste Discharge Requirements (WDRs) in either Region 1 or Region 2, they are strongly encouraged as the best possible means of managing potential water quality and public health impacts from AFOs. The completion of a CNMP will significantly help dairy operators in the North Coast Region meet future regulatory standards now being developed as part of a *Conditional Waiver of Waste Discharge Requirements* program.

Funding assistance for the development and implementation of CNMPs is being made available through USDA NRCS district field offices and partner organizations such as Western United Dairywomen. USDA and EPA are both committed to promoting locally-led conservation efforts as one of the most effective ways to help AFO owners and operators achieve compliance with state and regional water quality standards. Funding for this guidance document was made available through the State Water Resources Control Board

with technical support from USDA NRCS. We hope that the guidance provided in this handbook will assist dairy operators in the North Coast Region prepare for the regulatory future.

### **CHANGING PRACTICES IN THE NORTH COAST REGION**

This handbook is intended to provide pasture-based dairy farmers in northern California with a basic understanding of the principles and practices that inform comprehensive nutrient management planning. The guidance provided in this document grew out of a unique partnership between the Gold Ridge Resource Conservation District (Gold Ridge RCD), USDA NRCS, the University of California Cooperative Extension (UCCE), Western United Dairywomen, Clover-Stornetta Farms and a handful of dairy operators in Southwestern Sonoma County.

### **THE ESTERO AMERICANO WATERSHED DAIRY ENHANCEMENT PROGRAM**

Over the last five years, the Gold Ridge RCD and its partners have been working together to overcome obstacles to environmentally sustainable farming practices. Through grants from the State Water Resources Control Board and the State Coastal Conservancy, the Estero Americano Watershed Dairy Enhancement Program was developed to gain a better understanding of the conditions and constraints under which local dairy producers operate, and to identify the types of technical and funding assistance that would be needed to improve nutrient management practices on north coast dairies.

The program provided one-on-one technical assistance, soil and manure sampling services, a series of workshops on nutrient management, and funding assistance to upgrade infrastructure and land application equipment. Through this collaborative planning process, we found that dairy farmers in the region are highly motivated by rising feed and fuel costs to increase the



Landowner standing in front of new manure irrigator gun and reel.

productivity of their pastures and silage fields. This was particularly true for organic dairy producers who are now required to keep animals on pasture for a minimum of 120 days a year.

Over the course of program, we found that the key constraints to improving on-farm nutrient management planning were 1) a lack of needed technical assistance, 2) inadequate land application equipment, and 3) inadequate grazing infrastructure (i.e., cross fencing and water development). Once these constraints were addressed, the dairy operators in the program were well on their way to achieving on-farm nutrient balance and applying manure nutrients to farm fields based on plant nutrient requirements (agronomic rate).

Key changes in nutrient management on the dairies involved in the program included 1) better understanding of the nutrient content of their manure, 2) better understanding of soil nutrient reserves, 3) improvements in forage species selection, 4) better solids separation and increased use of composting,

5) more control over the timing and rate of manure application, 6) adoption of better stormwater management practices, and 7) the adoption of grazing best management practices.

## **ORGANIZATION OF THE HANDBOOK**

The first chapter of the handbook addresses the concept of *Nutrient Balance* and provides a series of strategies and best management practices (BMPs) for reducing the concentration of excess nutrients on the dairy. Chapter 2 of the handbook describes the types of information a producer will need to have and understand in order to develop a nutrient management plan. The chapter discusses the importance of understanding basic soil characteristics, the nutrient concentrations in manure, as well as the nutrient requirements of crops and forages. Basic guidelines are also provided for land application of manure, including the amount, timing, and frequency of fertilizer applications.

The final chapter addresses the need for better pasture management on coastal dairies, and describes a series of recommended BMPs to reduce both the concentration of pollutants and the potential for pollutant movement to drainages and streams. Lastly, the handbook includes a number of important appendices which provide technical guidance on 1) soil and manure sampling techniques, 2) how to read sampling lab reports, and 3) how to use this information to make more informed decisions on managing and utilizing manure nutrients. It is the hope of the authors that this information will be used to enhance on-farm productivity and the long-term viability of the dairy industry in northern California.

## CHAPTER 2

# ACHIEVING NUTRIENT BALANCE

Typically, nitrogen (N) and phosphorus (P) are the nutrients targeted in nutrient management plans because they are found in relatively large quantities in manure, and if mismanaged are likely to have the most adverse effect on the environment. Nitrogen and phosphorus can leach from the soil or be transported in stormwater runoff, entering streams and coastal embayments where it fertilizes aquatic plants and can cause toxic algae blooms, depleting oxygen from the water column and threatening aquatic life. Elevated levels of ammonia-nitrogen are also highly toxic to fish. Although less harmful to the environment, accumulations of potassium in the soil can lead to excess levels in forage crops, which is potentially harmful to livestock. Animal manure also contains chemicals and pathogens (protozoa, viruses, and bacteria) that may negatively impact aquatic and terrestrial organisms.

## NUTRIENT CONCENTRATION ON DAIRIES

There are many reasons why nutrients become concentrated on dairy farms, but chief among these is a reliance on imported feeds and forages. Unlike pasture-based beef cattle operations, which rely heavily on homegrown forages to meet livestock nutritional requirements, dairy farmers in the North Coast Region rely on large quantities of supplemental feeds to meet

the nutritional requirements of milking herds. This reliance on imported feeds and forages has allowed dairy farmers to support herd sizes larger than their land would normally support, creating higher concentrations of animals and therefore higher concentrations of manure production. If the manure is then land applied, and the nutrients in the manure exceed crop and forage nutrient demands, surplus nutrients will either build up in the soil or be washed away by winter rains.

In addition, for many years, standard dietary recommendations for crude protein and phosphorous intake did not take into consideration the amount of excess nutrients excreted by dairy cattle and the subsequent effects on the environment. In response to growing environmental concerns about nutrient imbalances and accumulations on dairies, the National Research Council (NRC) conducted extensive research to determine the actual nutritional requirements of dairy cows. The NRC released new standards in 2001 that significantly reduced recommended crude protein and phosphorous intake levels. Managing and reducing the level of excess nutrients in purchased feed is one of the few easily quantifiable methods for reducing excess nutrient accumulations on dairies.

## NUTRIENT BALANCING

Unless the amount of nutrients arriving on the dairy is roughly balanced by the amount leaving in managed products (e.g., cull animals, milk, compost etc.), nutrients will continue to accumulate on the dairy. Identifying ways to achieve a nutrient balance is a critical first step in the nutrient management planning process. The table below can be used to identify potential indicators of nutrient imbalance on a dairy. If the answer to any of these questions is affirmative, there is a high likelihood that improvements can be made to improve on-farm nutrient balance.

TABLE 1.1. NUTRIENT BALANCE CHECKLIST			
Yes	No	Don't Know	
			Soil phosphorus levels for the majority of fields are increasing with time.
			Soils phosphorus levels for the majority of fields are identified as "High" or "Very High" on the soil test.
			The majority (more than 50%) of the protein and phosphorus in the ration originates from off-farm sources.
			Livestock feed programs routinely contain higher levels of protein and/or phosphorus than National Research Council (NRC) or the California Dairy Quality Assurance Program recommendations.
			A manure nutrient management plan is not currently used to determine appropriate manure application rates to crops.
			Less than 2.5 acres of cropland is available per animal (1,000 lbs live weight), and no manure is transported to off-farm users.
Adapted from: <i>Whole Farm Nutrient Planning. Livestock and Poultry Environmental Stewardship Curriculum. LEPS Website: www.lpes.org.</i>			

Since livestock utilize only 10 to 30% of the nutrients they consume, the bulk of the nutrients imported in the form of purchased feed are excreted in manure. An average 1,400-pound dairy cow produces approximately 148 pounds of feces and urine per day. As a rule-of-thumb, a dairy cow will excrete:

- 75 to 80% of the nitrogen,
- 80% of the phosphorus, and
- 90% of the potassium it consumes.

On a yearly basis, this equates to a generalized production of 300 lbs of nitrogen, 153 lbs of phosphorus, and 175 lbs of potassium depending on diet, milk production rates, and days in milk.

## BEST MANAGEMENT STRATEGIES AND PRACTICES FOR ACHIEVING ON-FARM NUTRIENT BALANCE

Decisions regarding ration formulation and feeding strategies play a critical role in determining nutrient excretion by dairy cattle. Feeding strategies, milk production rates, and herd management systems each influence manure nutrient concentrations. Increasing on-farm forage production is another important way to reduce the amount of nutrients brought onto the farm. Composting manure and exporting it off the farm is the most direct way to achieve nutrient balance, where land for manure application is limited. Transporting compost to leased land (off farm locations) is an excellent way to improve forage productivity on pastures used for heifers and dry cows.

### Effective best management strategies and practices for achieving nutrient balance include:

- Group and feed animals based on their nutrient requirements.

- Balance rations according to NRC guidelines (2001) for protein and phosphorus.
- Limit the use of high-phosphorous by-product feeds.
- Increase high quality, homegrown forages in rations.
- Compost and export manure as a managed output.

### Group and Feed Animals Based on Their Nutrient Requirements

A useful way to reduce nutrient waste on a dairy is to group and feed animals according to reproductive status and milk production rates. If animals are grouped in this way, rations can be formulated that are closer to the animal’s nutritional requirements and will minimize overfeeding. A dairy nutritionist should be consulted to help determine a manageable number of groups based on the size and operation of the dairy. At a minimum, heifers should be managed and fed in several groups based on age. Where possible, dry cows should be managed in two groups (drying off until three weeks before calving and within three weeks of calving) (Stallings and Knowlton, 2005).

### Balance Ration Protein (N) and P to 2001 NRC Guidelines

The modern dairy cow has the genetic potential for high milk yields if fed high quality feed. Nutritionists use science and experience to design diets that will maximize milk production, and they tend to err towards adding an overabundance of nutrients rather than risk underfeeding the cow. Typically, protein and phosphorus have been overfed in the past, but recent nutritional studies have started to focus on adjusting cow diets in order to lower nutrient levels in manure. This can save the farmer the expense of both procuring and disposing of the extra nutrients.

The 2001 NRC guidelines have revised protein requirements for lactating cows. Protein is an expensive feed ingredient, and cows overfed protein must expend energy to rid their

rumen of toxic ammonia. Lower levels of protein can increase milk production and result in lower nitrogen concentration in manure. Phosphorous and other minerals are small costs in animal diets, so reducing their amounts in diets is more important environmentally. Restricting excess phosphorus in the manure has become an area of emphasis in livestock and poultry research. All dairy operators working with a nutritionist should ask for an update on current protein and mineral supplementation research and review diet rations.

The 2001 NRC guidelines have also revised phosphorus requirements for lactating cows. Revised requirements are now between 0.32% and 0.38% of dietary dry matter (Table 1.2). The reduction in phosphorous requirements was based on published research in high-producing dairy cows, and improved estimates of the availability of phosphorous in feed.

*Recent research confirms that high-producing dairy cows require approximately 0.38% phosphorous in the dietary dry matter for optimal milk production and reproductive performance.*

**TABLE 1.2. DIETARY PHOSPHORUS RECOMMENDATIONS OF THE NATIONAL RESEARCH COUNCIL (JANUARY 2001)**

Milk Production Level (lbs/day)	Dietary P Level (%)
55	0.32
77	0.35
99	0.36
120	0.38

### Limit the Use of High-Phosphorus By-Product Feeds

Concerns about the quality and consistency of forages can often lead to an over-reliance on feed supplements. Implementing forage and feed analysis as a quality control practice can minimize these concerns and lead to more efficient use of feed supplements.

Ingredient selection can play a major role in reducing nutrient excretion. Many common feeds are high in phosphorus, but with some minor changes in ingredient selection, it is possible to lower the phosphorus level of the diet from 0.44% to 0.36% of dry matter. Table 1.3 provides information on the percent phosphorous in a number of common supplements.

TABLE 1.3. INGREDIENT PHOSPHORUS LEVEL	
Ingredient	% Phosphorus in Dry Matter (DM)
Brewers grains (wet)	0.67
Canola meal	1.10
Distillers grains	0.83
Corn gluten feed	1.00
Corn gluten meal	0.60
Hominy	0.65
Whole cotton seed	0.60
Cotton seed meal	1.15
Soybean meal 48% CP	0.70
Wheat middlings	1.02

*Source: NRC Dairy Cattle 2001, Table 15-3*

### Increase Homegrown Forages in Rations

Increased use of homegrown forages provides a net reduction in the amount of nutrients brought onto the dairy and reduces excess nutrient accumulations in soils. High quality legume and grass forages contain more protein, less fiber and more energy than lower quality forages. In order to maximize forage in the ration, a complete forage analysis should be conducted monthly to monitor quality and to make ration adjustments as needed.

#### Tips for Increasing Forage Quality:

- Improve soil fertility
- Increase the percentage of legumes (i.e., clover, birdsfoot trefoil) grown in pastures

- Use rotational grazing practices to harvest forages at optimal growth stages

Under ideal conditions, manure from dairies that import feed would be delivered back to the farms which grew the feed-stuffs. The cost of trucking this raw manure, with its high water content and low nutrient density, limits the feasibility of shipping it back to the place where imported feed was grown (most often the alfalfa region of central California). If more forage was grown locally, the possibility of returning manure to the forage-producing fields would increase.

If imported feed can be replaced with homegrown feeds, the farm will be much closer to nutrient balance. The example below demonstrates that growing a higher portion of feed on the farm can significantly alter on-farm nutrient balance. This simplified example uses one cow and two diet choices. No allowance for the sale of cull animals was made.

Table 1.4 shows two diets designed to feed a 1,400-pound Holstein cow producing 80 pounds of milk per day. Cow eating Diet A receives more homegrown feed, while the cow eating Diet B receives more feedstuff that comes from off-farm.

TABLE 1.4 . A MORE BALANCED NUTRIENT DIET USING HOMEGROWN FORAGE		
	Diet A in lbs	Diet B in lbs
Pasture, dry matter intake	15	0.0
Winter forage silage, as fed	27	35
Alfalfa hay, as fed	0.0	13.3
Ryegrass hay, as fed	5.6	9.7
Grains, as fed	21.9	19.1
Added minerals	1.2	1.2

Table 1.5 demonstrates that feeding a higher portion of home-grown feed can reduce the amount of excess nitrogen and phosphorous by 10 to 15 times. The data provided assumes that all the ryegrass hay and silage is grown close enough to

the dairy to facilitate returning manure to the fields as fertilizer. Diet A contains no imported alfalfa and all forages are locally produced with the assumption that the dairy returns cow manure to the silage and hay fields. Diet B uses 15 pounds of imported alfalfa per cow daily which results in large surpluses of nitrogen and phosphorus; whereas locally-based Diet A is nearly in nutrient balance for the farm system.

TABLE 1.5. NUTRIENT BALANCE FOR DIET A AND DIET B, ALL UNITS ARE POUNDS PER COW PER YEAR.			
	Nutrients Imported to farm (lbs/year)	Nutrients Exported as Milk (lbs/year)	Surplus Nutrients (lbs/year)
<b>Diet A</b>			
Nitrogen	213	188	25
Phosphorus	37	36	1
<b>Diet B</b>			
Nitrogen	409	188	221
Phosphorus	52	36	15

**Composting Manure**

If land area for crop and forage production is limited, composting and exporting manure from the farm as a managed output may be one of the only options for achieving on-farm nutrient balance. Fortunately, there is a growing demand for composted manure in California. For example, biodynamic and organic crop farms are prohibited from using chemical fertilizers, and instead use animal manure, the preferred source being compost.

Composting manure can greatly reduce both its weight and volume, while conserving much of its nutrient value. Properly composted manure can be used as a soil amendment or as a source of bedding. It is also much easier to transport, and can be land applied to steeper soils, transported to leased land, or sold on the market. Composting

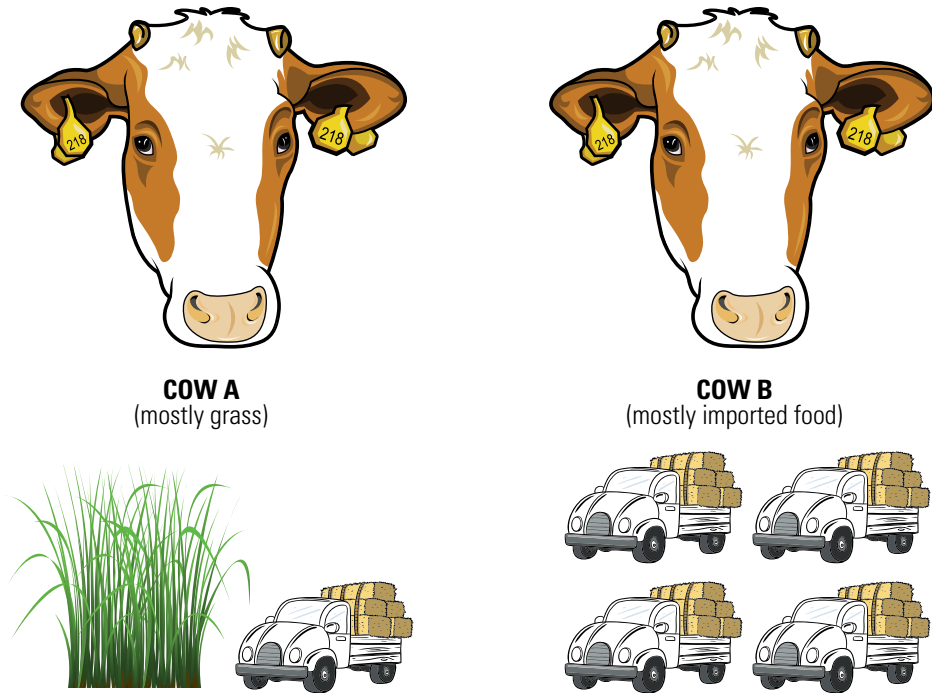


Figure 1.1

is also an effective way to kill pathogens and weed seeds in manure. This is an important additional benefit for organic dairy farmers or for operators in watersheds where pathogen pollution in surface waters is a serious regulatory concern.

Composted manure is more valuable and marketable than unprocessed manure for several reasons:

- Compost has higher concentrations of nutrients
- The nutrients in compost are in a more stable form (less likely to be lost to the environment)
- Compost has minimal unpleasant odor
- Most weed seeds and pathogens are destroyed during the composting process



Compost pile  
(photo courtesy  
of Jeff Creque).

- Composted manure can be used on-farm by dairy operators as bedding for cows
- Compost provides the soil with organic matter and slow release nutrients

Most dairy farms have all the equipment needed to make compost. A tractor with a loader and a thermometer with a long probe (3 feet or more) are the minimum equipment needed, although a sealed pad may be required if compost is made or stored in winter. The biggest inputs usually needed are operator time and management time.

The raw ingredients used for making compost should be thoroughly mixed and formed into windrows less than nine feet high. Composting works best when the initial windrows have a 50-60% moisture content, a carbon to nitrogen ratio of 25 to 1, and a bulk density of about 1,100 pounds per cubic yard. Typically, fresh cow manure is too wet (about 85% moisture content) and too high in nitrogen to compost very well.

Drying the manure and adding waste hay, straw, rice hulls or wood chips can result in a good starter mix for a compost pile.

A compost pile that maintains an internal temperature of at least 135° F for two weeks and has been turned and re-mixed at least five times is considered to be mostly free of viable weed seeds. Turning helps maintain temperature by adding oxygen, and ensures that the windrow is well mixed. Be aware that the compost will continue to cure and produce heat. Building compost piles higher than nine feet tall can result in excessive heat buildup and can cause charring or even ignition of the compost. Compost fires are similar to fires in wet hay; dosing with water will not prevent the fire from starting up again. The burning pile must be pulled apart and allowed to cool.

Dry manure and compost are more efficient to transport than fresh manure or liquid manure. Most of the phosphorus will be in the dry manure and compost so these are ideal products to export off the farm. While dairy soils are often high in phosphorus from manure over-application, soils in California's North Coast are naturally low in phosphorus; therefore, non-dairy cropland may benefit from added phosphorus.



## CHAPTER 3

# NUTRIENT MANAGEMENT PLANNING

Nutrient Management Planning is a tool that can help ensure that you are getting optimal forage production from your pastures and silage fields. The goal of nutrient management planning is to apply the right amount of each nutrient required for plant growth at the proper time, based on crop/forage requirements and soil nutrient availability—this is what is meant by *agronomic rate*. The best on-farm source of nutrients is manure. Determining the amount of manure generated on the dairy, the amount of manure nutrients that will be available to growing crops and forages, and the appropriate application rates for individual farm fields can be a difficult process. Recognizing and accounting for potential nutrient losses to the environment during the handling, storage, and application of manure is an additional challenge. It is highly recommended that dairy operators seek technical assistance through USDA NRCS, Western United Dairymen, or another certified professional in developing nutrient management plans.

On many dairies in the North Coast Region, manure is applied in late summer or early autumn without adequate consideration of plant nutrient requirements, the nutrients already in the soil, or the potential for pollutant runoff to surface water or leaching to ground water. These manure management practices arose in response to 1) difficult farming conditions in coastal

watersheds, 2) a lack of alternative and affordable methods of land application, and 3) a shortage of nutrient management specialists to provide needed technical advisory services.

Dairy operators should not view nutrient management planning as a regulatory hoop to jump through, but rather as a management tool to identify:

- Investment priorities in infrastructure and/or equipment upgrades.
- Appropriate and cost-effective best management practices for improving water quality protection efforts.
- Nutrient optimization strategies for individual farm fields.
- Better forage crop selection and associated nutrient requirements.

## NUTRIENT MANAGEMENT PLANNING INVOLVES

- Sampling and understanding soil nutrient reserves
- Knowing crop and forage nutrient requirements
- Determining the nutrient content of manure
- Estimating total manure production rates

- Applying nutrients to individual farm fields at agronomic rates
- Best management practices for reducing losses to the environment, including soil loss through erosion.

### **BASIC COMPONENTS OF A NUTRIENT MANAGEMENT PLAN**

- An aerial photograph of the dairy, and a soils map of the fields.
- Soils and manure sampling results.
- A list of all nutrient sources and quantity (e.g., dry stack, liquids, compost, etc.)
- Realistic yield expectations for crops and forages.
- Recommended nutrient rates, timing, form, and method of application.
- Location of sensitive areas and associated restrictions (e.g., steep slopes, drainages, buffer zones).
- Guidance forms for record keeping, equipment operations and maintenance, and a field-by-field nutrient budget for nitrogen and phosphorus applications.

Most soils are comprised of the following:

- Minerals – about 45%
- Water – about 25%
- Air – about 25%
- Organic matter & living organisms – about 1 to 5%

### **UNDERSTANDING BASIC SOIL CHARACTERISTICS**

Soil is a mixture of minerals, water, air, organic matter and living organisms. Soil is a “storehouse” for plant nutrients, and provides the majority of essential elements needed for plant growth. To maximize plant productivity and reduce nutrient losses to the environment, it is important to understand the nutrient composition of your soils, as well as other soil characteristics such as soil pH, soil texture and soil structure that can significantly affect the fertility of your farm fields. Appendix C provides more detailed information on how to read a soil sampling report.

Most soils contain at least some sand, silt, and clay-sized particles. Soil texture refers to the relative proportions of these particle sizes in a soil (e.g., a sandy soil or a clay soil). Soils with a high percentage of sand also have the lowest capacity to hold nutrients and water. Nutrients applied to sandy soils can easily leach out with rainfall. Clay is the smallest mineral particle. Unlike sand and silt, however, most types of clays contain appreciable amounts of plant nutrients. Soils with high levels of either clay or organic matter have the largest soil nutrient reserves and water holding capacity. Clay soils are also easily compacted and can remain water saturated for long periods during winter months. Care must be taken when applying manure to clay soils, which are highly prone to saturation and surface water runoff.

*Soil structure* refers to how well soil particles are held together or “aggregated” into larger clusters. Organic matter and clay are important binding agents that help create stable soil aggregates. Soil has good structure if it is porous and crumbles easily in your hand. Soil structure has an important influence on plant growth. The movement of air and water through the soil is dependent upon the porosity of the soil (the spaces within and between the aggregates). Good soil structure enhances plant growth by increasing infiltration and soil water holding capacity, and by enhancing soil aeration, heat transfer, and plant root growth.

Although it is not possible to alter soil texture, soil structure can be either improved or destroyed by agricultural management practices. Management practices to improve soil structure include increasing soil organic matter, maintaining a proper soil nutrient balance, reducing soil tillage and compaction, and maintaining ample above ground plant cover and below ground root growth.

## SOIL NUTRIENT RESERVES

Plants require 17 essential elements. Three of these – carbon, hydrogen, and oxygen – plants take from air and water. The remaining 14 are typically absorbed from the soil by plant roots, and are divided into three groups: primary nutrients, secondary nutrients, and micronutrients. All of the essential elements are equally important for healthy plant growth and reproduction, though the amounts required vary depending on the plant. Plants typically take up more nitrogen and potassium than any other essential element, with the exception of carbon, hydrogen, and oxygen.

The annual nutrient requirements of crops and forages are much less than the total nutrient content of the soil, typically about 0.5 to 2 percent. However, the amount of soil nutrients that are readily available to plants in any year is also only a small fraction of the total nutrient content of the soil, typically from less than 1 percent to over 30 percent (5 percent is a rough average). This is why yearly crop requirements for some nutrients (typically nitrogen) can exceed the amount of soil nutrients in readily available form.

The organic component of soil, though usually less than 5 percent, holds a very high percentage of the soil's nutrient reserves. Over 90 percent of the nitrogen, 15 to 80 percent of the phosphorus, 50 to 70 percent of the sulfur, and some potassium and trace elements are derived from the organic matter in soil (Zimmer, 2000). Organic matter is therefore key to soil fertility and productivity.

Building soil organic matter not only increases the amount of nutrients stored in the soil, it also increases soil aeration, water infiltration and retention. Although manure is a valuable and important source of plant nutrients and organic matter for building healthy and productive soils, over application can result in significant nutrient losses to the environment and decreased soil fertility and plant growth.

In dryland agricultural systems, effective water holding capacity is probably the single most important soil property. Water holding capacity is determined by factors such as soil chemistry, depth, texture, organic matter, and extent of plant root growth. Maintaining high levels of organic matter in soils and ample vegetation on pastures and crop fields is the best way to prevent soil crusting and to promote water infiltration. Good plant cover protects the soil surface from the pounding effects of rainfall and sprinkler irrigation. Similarly, good root systems help hold soils in place, promote infiltration, and decrease the potential for soil loss in runoff water (California Plant Health Association, 2002).

## DAIRY MANURE AS A SOURCE OF FERTILIZER

Dairy manure can be used as a fertilizer to supply crops and forages with some or all of the essential macronutrients (nitrogen, phosphorus, and potassium) not otherwise supplied by the soil in sufficient amounts. Animal manures also contain micronutrients necessary for plant growth, such as calcium, sulfur, and magnesium. Regular additions of manure to cropland and pasture can greatly improve soil quality and fertility. For example, applying solid and composted manure to farm fields can significantly increase the amount of organic matter in soils.

### Organic and Inorganic Nutrients in Dairy Manure

Nutrients come in two major forms: inorganic and organic. Inorganic forms of nutrients, which are readily available to growing plants, are typically purchased as commercial fertilizers. Most of the nutrients in dairy manure are in organic form, and are not immediately available as a source of food to growing plants. Organic forms of nutrients include manure solids, crop residues, compost and sludges. In order to become plant-available, organic nutrients must first go through a mineralization process. Mineralization is the chemical conversion of

organic nutrients into inorganic forms that are plant available. It is performed by soil microbes and takes place over time.

The rate of mineralization is affected by soil temperature, moisture content, soil pH, and the availability of food for microbial activity. Dairy pastures and cropland that have consistently received manure applications typically have relatively high levels of soil organic matter and rich reserves of nutrients already present in the soil. In most cases, only 25 percent to 50 percent of organic manure nutrients will be available to plants in the same year they are applied. Organic nutrient sources such as manure are thus considered a “slow release” nutrient source.

### **N-P-K Concentrations in Manure**

Unlike inorganic commercial fertilizers, which can be manufactured and purchased based on recommended N-P-K ratios for specific crops or forages, manures do not have the appropriate nutrient forms and/or ratios to meet most plant nutrient requirements. The phosphorous to nitrogen

ratio in most dairy manure is roughly 1:2, but typical forage crops use 1 lb of phosphorus for every 4 lbs of nitrogen. This means that if manure is applied to meet the nitrogen requirements of a forage crop, twice as much phosphorus will be applied as is needed. Concentrations of N-P-K in manure can vary significantly based on factors such as:

- Animal diet
- The physical characteristics of the manure
- Dilution from rain or wash water
- The amount of bedding or feed mixed with the manure
- How the manure is collected and stored.

The only way to accurately determine the nutrient content of your manure is to have it sampled and lab analyzed just prior to land application. Each of the major manure sources (lagoon, dry stack, etc.) on the dairy must be sampled and analyzed individually to account for the wide variations in nutrient ratios and concentrations of different forms of manure. A single manure source can include large variations in nutrient content if it is not thoroughly mixed before spreading (refer to Appendix B for guidance on how to sample manure).

### **Liquid versus Solid Manure**

Nutrients in manure occur in both water soluble and insoluble forms. Insoluble nutrients are in an organic form, and are not immediately available for plant growth. Water soluble nutrients, on the other hand, are found in the liquid portion of excreted manure and in urine. Liquid manure contains much of the water soluble nutrients that are most readily available to growing plants. Most of the nutrient value stays with the liquids on dairy facilities where liquids and solids are separated. Spreading and disposal of liquids and slurries is thus relatively more important for maximizing fertil-

Technician calibrating a new manure irrigator gun and reel.



izer benefits and for pollution control than is disposal of dry solids (Gold Ridge Resource Conservation District, 1996).

**APPLY LIQUID MANURE APPROPRIATELY: SMALL, FREQUENT, AND SEASONALLY APPROPRIATE APPLICATIONS**

Liquid manure application is the most effective way to increase plant growth, but can also result in leaching losses to both surface water and ground water if not applied properly. Plants obtain carbon and oxygen through respiration, but acquire all other nutrients through their roots from the soil. These nutrients must be in a water soluble form in the soil to be available for plant uptake. Water soluble nutrients are extremely valuable and are immediately available for plant growth.

The key is to supply water soluble nutrients (e.g., liquid manure) at rates that match the nutrient requirements of the plants being grown. Applying liquid manure during the growing season can greatly increase forage production. Early season applications should be small and occur when soils are dry enough to avoid runoff or leaching to groundwater. Limit applications to less than 100 pounds of nitrogen per acre. Applying more than the plant is able to uptake will only result in leaching losses.

**TO AVOID PHOSPHOROUS BUILD-UP IN SOILS, SEPARATE SOLIDS**

A primary benefit of solids separation is that it provides dairy operators with greater control over the amounts and ratios of nutrients applied to farm fields. For example, one of the most effective ways to control and limit over-application of phosphorus is through adequate solids separation. Over 90% of the phosphorus in manure is in the solid fraction (Table 2.1). Dried or composted manure is much easier to handle and transport than slurry, and can be applied to less accessible fields or to leased land where soil phosphorus levels are



not elevated. Good solids separation also allows for more efficient application of the liquid fraction of manure.

Irrigator gun with reel spreading liquid manure onto pasture.

**TABLE 2.1. MANURE NUTRIENT CHARACTERISTICS**

Nutrient	Percent excreted in manure	
	Feces	Urine
Nitrogen (N)	48%	52%
Phosphorus (P)	97%	3%
Potassium (K)	30%	70%
Calcium (Ca)	99%	1%

*Adapted from: Koelsch, R. Whole Farm Nutrient Planning. Livestock and Poultry Environmental Stewardship Curriculum. LEPS Website, www.lpes.org.*

**THE NITROGEN FRACTION OF MANURE**

Plants require more nitrogen than any other plant nutrient, and sufficient amounts of nitrogen are essential for maintaining good crop and forage productivity. Of all the nutrients in manure, nitrogen is the most vulnerable to environmental losses. Although half of the nitrogen excreted by dairy cows is in a form readily available to plants (ammonia), most

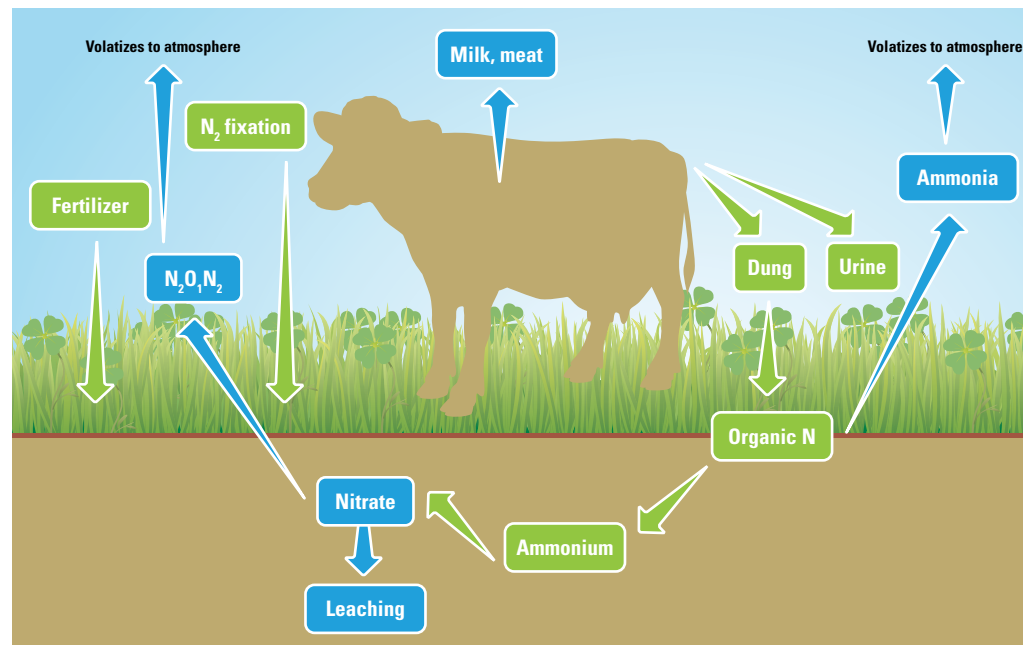
of this will be lost to the atmosphere through ammonia volatilization prior to and during land application.

Manure is often over-applied to compensate for potential environmental losses of nitrogen. Therefore, nitrogen concentrations in manure and appropriate application rates need to be carefully determined to avoid adverse air and water quality impacts as well as soil acidification (Kinsey and Walters, 2006). Steps taken to conserve the fertilizer value of manure nitrogen will also help minimize adverse impacts to the environment.

### THE PHOSPHORUS FRACTION OF MANURE

Manure solids and slurries contain almost all of the phosphorus excreted by livestock. This is because phosphorus chemically binds to organic matter. Phosphorus will also chemically bind to soil particles, and once land applied, will build up in

**FIGURE 2.1. THE NITROGEN CYCLE**



the soil until utilized by plants. It is much easier to quantify and manage the manure nutrient value of phosphorus than nitrogen. While phosphorus is less mobile than nitrogen, research has shown that high levels of soil phosphorus directly correlates with elevated levels of phosphorus in surface water runoff (Sturgul et al., 2004). Farm fields that have consistently received manure applications typically have sufficient soil reserves of phosphorus to meet plant nutrient requirements.

### THE POTASSIUM FRACTION OF MANURE

Most of the potassium excreted by livestock is in a water soluble form. Potassium is not known to cause water quality impacts, although excessive levels of potassium in crops and forages can lead to livestock health problems such as milk fever. Soils naturally contain many thousands of pounds of potassium per acre, though only a small percentage is available to plants (1 to 10 percent). Large amounts of potassium are removed from the soil when vegetation is removed, as in a silage or hay crop (California Plant Health Association, 2002).

### MANURE PRODUCTION RATES AND CHARACTERISTICS

Estimating the amount of manure generated on the dairy as well as its nutrient content are critical steps in the nutrient management planning process. With these estimates in mind, it is then possible to figure out the approximate amount of land that will be needed to apply the manure at agronomic rates. Many producers may already have accurate estimates of yearly manure production rates based on annual manure hauling records. Knowing the amount and characteristics of the manure that is hauled annually will make it much easier to preplan application rates based on manure sampling results.

<b>TABLE 2.2. DAILY MANURE PRODUCTION</b>				
<b>Animal</b>	<b>Size (lbs)</b>	<b>Total Manure</b>		
		<b>(lbs/day)</b>	<b>(ft<sup>3</sup>/day)</b>	<b>(gal/day)</b>
Lactating Cow	1,000	106	1.7	12.7
	1,400	148	2.4	17.7
Dry Cow	1,000	82	1.30	9.7
	1,400	115	1.82	13.6
Heifer	750	65	1.0	7.8
Veal Calf	250	9	0.14	1.1
Calf	150	13	0.20	1.5

*Source: Lorimor et. al. 2000. Manure Characteristics. MWPS-18 Section 1, Table 6.*

Using book values (Table 2.2), a 1,400-pound dairy cow produces approximately 148 pounds of feces and 18 gallons of urine per day. In one year, she will produce roughly 27 tons of solid manure and 6,570 gallons of urine. A 200 cow milking herd would produce on the order of 5,400 tons of solid manure a year. A manure truck with a 20 cubic yard capacity can haul approximately 15 tons of fresh manure (1 cubic yard equals 0.75 tons). Hypothetically, it would take 360 truckloads to haul the 5,400 tons of solid manure.

The weight of the manure and its nutrient content per ton is determined by moisture content. Fresh manure has a moisture content of roughly 85%. This is important to know because nutrient concentrations provided in manure sampling reports are expressed on a 100% dry matter basis. If you reduce the moisture content of the manure by half, you will eliminate half its weight. In this example, good solids separation or composting could save an operator the fuel and labor costs of hauling an additional 180 truckloads of manure.

Reducing the weight of the manure does not reduce its nutrient content in equal measure. Most of the nutrient value is retained in the manure, with the exception of nitrogen. A percentage of the nitrogen will be lost to the

atmosphere through ammonia volatilization. The same nitrogen loss will occur, however, if the wetter manure is applied to farm fields without incorporation into the soil.

To estimate how many acres would be needed to apply the 5,400 tons of manure from 200 cows at an agronomic rate, you would need to know 1) the nutrient content of the manure, 2) the amount of nutrients needed by the crop, and 3) the amount of nutrients that will be supplied by the soil. Information on how to use manure and soil sampling results is provided in Appendices C and D.

### **MATCHING NUTRIENT APPLICATIONS TO CROP AND SITE POTENTIAL**

Nutrients should be applied to farm fields based on crop nutrient requirements (amount and timing) and yield expectations. Two basic factors control the amount of nutrients that should be applied on fields growing forage for dairy cows: 1) whether a field is grazed or mechanically harvested, and 2) forage production potential at the site.

#### **Mechanically harvested forage versus cow harvested forage**

Appropriate nutrient application rates will vary based on what is grown and how it is harvested. Because grazing cows recycle nutrients through urine and feces, grazed pastures will need little added fertilization, whereas mechanically harvested fields will need more. Areas of higher plant productivity will require a higher application rate than sites that have lower yield potentials.

Most of the nutrients required for a healthy pasture come directly from the grazing cow. In fields that are grazed, cows excrete 80-90% of consumed nutrients as feces and urine. The amount of additional manure that should be applied to grazed pastures will be about 1/5 of that applied to mechanically harvested fields. A plant's ability to utilize nutrients

#### **Forage Production Potential**

Maximum amount of forage a certain location can produce with proper fertilization.

is limited by soil quality (*site potential*). For mechanically harvested fields it is much easier to determine the amount of nutrients removed (calculated from yield records) and therefore easier to determine the amount of nutrients to apply to areas where grass or other crops were harvested.

### Site Potential

There are many factors that affect optimum plant growth. The site potential of a location refers to the capability of that location to support plant growth, and includes factors such as:

- Soil erodibility
- Frequency of flooding
- Average rainfall
- Depth of topsoil
- Slope, aspect, and soil texture

(*Vernon C. Miller, Soil Conservation Service, 1972*)

Plant productivity correlates directly to a location's site potential. Once a plant receives all of the nutrients it needs to grow, plant growth will only be limited by temperature and availability of water. Water available for plant uptake is determined by both rainfall and by the available water holding capacity of the soil. Deep, flat, alluvial soils have higher water infiltration rates and store more water in the rooting zone (Thompson, 1993). The differences in grass growth can be at least three times greater for flat alluvial soils than shallow or eroded soils, and therefore manure applications should be applied accordingly.

Steep, eroded, and shallow southern facing slopes dry out quickly and have the least potential for plant growth (*ibid*). North facing slopes tend to stay damp longer than south facing slopes and therefore have higher crop yield potentials (*ibid*). Topographic and soil maps will help to determine which parts of the farm should be fertilized the most. An exact manure

application rate that matches the site potential may be hard to calculate, but if application rates are recorded, a dairy operator can adjust the rates of future applications based on results.

### Plant Nutrient Requirements

Pastures along the north coast of California consist mostly of cool season grasses and some legumes. There is little difference in nutrient uptake requirements between different cool season grass species. For example, one ton of quality forage (at 90% dry matter) contains about 35 pounds of nitrogen, 3.5 pounds of phosphorus, and 40 pounds of potassium. If the soil alone is not providing enough nutrients for maximum growth, manure can be added. To recycle the maximum amount of manure, you should choose the species that grow best in your area, as they will require the most nutrients.

Growing legumes that are well adapted to the North Coast Region can add substantial amounts of nitrogen to the soil. Legumes can obtain some of the nitrogen they need from the air via nitrogen-fixing rhizobia. Rhizobia grow symbiotically on legume roots and add nitrogen to the soil pool on the order of 100 to 200 pounds per acre annually. Adapted legumes for the north coast include annual and perennial clovers, vetches, medics and birdsfoot trefoil.

Building soil nitrogen with legumes is a slow process since the rhizobia provide nitrogen first to the legume. Only when the legume decays or is consumed by the cow can the extra nitrogen become part of the soil nitrogen pool. This nitrogen is incorporated into the soil as organic matter and slowly released. Legumes grow better in soils with a neutral pH and require more sulfur than pure grass stands. Correcting these factors may be required to fix significant amounts of nitrogen through legumes.

In fields that are mechanically harvested, yield records can be used to determine plant nutrient requirements.

Adding excessive amounts of manure will not compensate for poor site conditions.



Yield records for mechanically harvested feeds work well for estimating appropriate fertilizer application rates. The yields of silage should be converted to a 90% dry matter yield basis before calculating nutrient needs.

*For pastures or unrecorded yields, assume 5 tons of dry matter per acre on good soils and 1.5 tons per acre on poor soils.*

Periodic soil tests will indicate how accurate your estimates are compared to actual plant nutrient uptake rates. Based on yield estimates and nitrogen requirements for various species grown in the area (Table 2.3), 5 tons of forage will require about 180 pounds N, 18 pounds P and 200 pounds K.

Crop Code	Crop Name	Units	N requirement lbs/Unit	Average Crop Yield Tons/Acre
1	Alfalfa hay	tons	60	8
2	Barley (grain)	tons	64	3
3	Barley Silage, boot stage	tons	16	8
4	Barley Silage, soft dough	tons	10	16
6	Corn (grain)	tons	48	5
7	Corn (silage)	tons	8	30
9	Clover-grass, hay	tons	38	6
10	Oats (grain)	tons	100	2
11	Oats silage, soft dough	tons	10	12
12	Oats (hay)	tons	40	4
13	Tall Fescue, hay	tons	32	6
15	Sorghum	tons	50	4
16	Sudan silage	tons	11	8/cutting
17	Sudan hay	tons	32	8
18	Sugar Beets	tons	9	30
19	Triticale, boot stage	tons	15	12

Crop Code	Crop Name	Units	N requirement lbs/Unit	Average Crop Yield Tons/Acre
20	Triticale, soft dough	tons	10	22
21	Wheat (grain)	tons	58	3
22	Wheat Silage, boot stage	tons	16	10
23	Wheat Silage, soft dough	tons	11	18
24	Orchardgrass, hay	tons	35	6
25	Ryegrass, hay	tons	32	6
26	Timothy, hay	tons	35	6

*Barley, Wheat, Oats, Sudan, and Triticale values are from UCCE. Other values are from Western Fertilizer Handbook where available.*

## BASIC GUIDELINES FOR LAND APPLICATION OF MANURE

### Pre-Plan Manure Application

- Quantify and keep records of manure production rates.
- Know your spreader capacity and calibrate all equipment.
- Know your manure pond holding capacity. A white vertical pole anchored or mounted in the deepest section of the lagoon can be marked off at one-foot increments to show pond depth.
- Sample and test all sources of manure for nutrient content (e.g., lagoons, dry stacks, and compost) prior to land application.
- Test soils every 3 to 4 years, and refer to test results each year when planning manure applications.
- Know your soil types (sandy, clay, loam).
- Know your crop nutrient demands and keep good crop yield records.

### **Reduce Nutrient Losses and Runoff Potential**

- Incorporate manure into the soil where possible to reduce ammonia volatilization and to prevent nutrient losses through runoff.
- Do not apply manure within 200 feet of a surface waterbody or within a floodplain unless incorporated into the soil.
- Do not apply manure to grassed waterways, drainages, or other areas where water flow concentrates.
- If soil-test phosphorous levels reach 75 ppm, plant phosphorous-demanding legume crops (e.g., clovers and vetch), adopt soil conservation practices such as vegetated buffer strips, and reduce solid manure application rates.
- Apply solid manure at least one month prior to a runoff generating storm event.
- Do not apply manure to saturated soils.
- Use good solids separation or compost manure to improve handling and application.
- Use soil conservation practices to prevent erosion and runoff such as stream buffers, avoidance of steep slopes, and vegetated filter strips around application areas.
- Maintain healthy, productive pastures to enhance plant nutrient utilization.

### **Application Rates**

- Apply manure nutrients at agronomic rates.
- Match nutrient application rates to site potential.
- Use caution when applying manure to grazed pastures. Grazing animals will recycle manure nutrients. Reductions of 25% to 50% of the annual nitrogen requirement have been recommended in some states.

- Credit all sources of nitrogen, including soil nutrient reserves.
- To minimize nitrate leaching from sandy soil, apply manure near planting time. To minimize leaching in general, apply smaller amounts of nitrogen more often rather than a large amount at one time.
- Schedule irrigation/fertigation to minimize runoff potential.

### **Which Manure Where?**

- Avoid applying both solids and liquids to the same field.
- In general, haul manure with the highest nutrient content to the farthest fields. On many dairies, fields easiest to access often receive excess application rates.
- Apply manure with the lowest nutrient content to the closest fields. If possible, irrigate with collected runoff water and lagoon effluent.
- To receive the most value from your manure, apply high-phosphorous manure to fields with the lowest soil phosphorus test levels.

## CHAPTER 4

# BEST MANAGEMENT PRACTICES

## to Reduce Nutrient, Pathogen and Sediment Pollution in Runoff from Dairy Facilities and Farm Fields along the North Coast of California

The steep slopes, highly erodible soils, high annual rainfall and extensive drainage network characteristic of north coast watersheds present numerous environmental constraints and management challenges for pasture-based dairy farms. The following chapter provides a number of recommended best management practices (BMPs) to help dairy operators reduce the amount of nutrients, sediment, and pathogens entering surface waters in the North Coast Region.

BMPs to control and reduce agricultural pollution can be either structural (e.g., manure containment and storage facilities, barns, or fencing) or management-oriented (e.g., rotational grazing, composting or nutrient management planning). BMPs have varying levels of effectiveness in controlling or reducing pollutant concentrations and delivery to surface water. To maximize effectiveness, combinations of practices should be selected that reduce both the concentration of a pollutant as well as the likelihood of delivery to surface or ground waters.

A fundamental goal of nutrient management planning is to apply the right amount of manure nutrients, in the right place and at the right time to maximize both forage/crop yields and water quality protection. Nutrient management helps to reduce pollutant loadings from land applica-

tions of manure, but additional management practices are highly recommended for dairy operators along the North Coast to prevent agricultural nonpoint sources of pollution from entering sensitive coastal bays and tributaries.

Nonpoint source pollution is an accumulation of many small pollution sources distributed on the landscape that are delivered to waterbodies during stormwater runoff events. To effectively manage agricultural nonpoint sources of pollution from dairy facilities and farm fields, a series or system of best management practices should be adopted. Combinations of best management practices should be selected that:

- Reduce the concentration of pollutants on the land susceptible to stormwater runoff, and
- Limit or manage the pathways for pollutant movement to surface water and groundwater.

### POLLUTANTS OF CONCERN AND THEIR DELIVERY

In the North Coast Region, pollutants associated with animal agriculture are primarily nutrients, pathogens, and sediment. Efforts to manage nonpoint sources of pollution from dairy facilities and farm fields require reductions in the concentra-

tion of pollutants as well as controls on possible pathways of pollutant movement to ground and surface waters.

For example, composting can eliminate nearly all the pathogens in manure. Aging non-composted manure solids for a month or two prior to land application can also significantly reduce concentrations of pathogens. Maintaining vegetated filter strips or buffers around manure stockpiles or composting sites, livestock heavy use areas, and pasture and silage fields receiving land applications of manure are BMPs designed to prevent the movement of pollutants off site.

### **POLLUTANT CONCENTRATIONS**

The potential load or loading rate of a pollutant to a water body is determined by both the concentration of a pollutant and the amount of runoff. Areas of high pollutant concentration subject to large volumes of surface water runoff will produce the highest pollutant loads to surface waters. The location and concentration of potential pollutants and the amount of runoff on a dairy farm are highly variable and site specific.

Manure stockpiles and lagoons will have the highest concentrations of nutrients and pathogens on a dairy facility, though if contained and managed properly, will not be subject to high volumes of surface water runoff. Livestock heavy use areas such as feeding and loafing areas, on the other hand, have high concentrations of pollutants that are also potentially subject to high volumes of surface runoff. This may also be the case for pastures and silage fields where manure has been applied (Lewis et al, 2005).

### **POLLUTANT PATHWAYS**

Understanding drainage patterns on the landscape as well as through and around facilities and livestock heavy use areas is a critical first step in managing potential pollutant path-

ways. Water that does not evaporate or percolate into the soil moves as surface runoff into streams and other water bodies. Understanding runoff rates is also important when selecting best management practices. Some areas are far more susceptible to runoff than others, depending on slope, soil types, soil saturation, surface area and surface permeability.

Runoff occurs when rainfall or irrigation exceeds the infiltration rate of the soil. Sandy soils have much higher infiltration rates than clay soils. Areas around livestock facilities or places where animals frequently travel or congregate typically have compacted soils with very low infiltration rates. These areas will produce runoff during most storm events. Best management practices designed to reduce runoff from agricultural operations typically rely on methods to slow or capture runoff, increase infiltration into soils, and filter pollutants through vegetation.

### **NUTRIENTS (NITROGEN AND PHOSPHORUS)**

Nitrogen (N) and phosphorus (P) are both nutrients and common agricultural pollutants. When these nutrients enter surface water, they can significantly degrade water quality and aquatic habitat. Nutrients stimulate aquatic plant growth and decrease the amount of oxygen in the water column needed to support fish and other aquatic organisms. Ammonia, at even slightly elevated levels, can be toxic to fish. Nutrients enter surface water bodies in stormwater runoff, either dissolved in water or attached to eroded soil particles or organic matter.

Most of the phosphorus that reaches surface waterbodies is attached to soil particles.

#### **BMPs to reduce phosphorus loading to surface waters include:**

- Prevent phosphorus from building up in the soil.
- Reduce erosion from farm fields or livestock heavy use areas.

- Intercept or filter pollutants before they reach drainages and surface water bodies.
- Restrict livestock access to drainages and stream corridors, particularly during the rainy season.

Nitrogen is delivered to surface water bodies along numerous pathways. In its organic form, it can be delivered to surface water attached to organic matter or eroded soil particles. The nitrate-N form of nitrogen, on the other hand, does not easily attach to soil and sediment, making it highly mobile in water. Nitrate-N can reach surface water bodies either in surface water runoff or in groundwater that discharges to wetlands and streams.

**BMPs to control nitrogen pollution include:**

- Apply manure and other fertilizers to farm fields at agronomic rates.
- Prevent runoff from manure stockpiles and livestock heavy use areas.
- Intercept or filter pollutants before they reach drainages and surface waterbodies.
- Restrict livestock access to drainages and stream corridors, particularly during the rainy season.

**PATHOGENS (BACTERIA, PROTOZOA, VIRUSES)**

Pathogens are microorganism such as bacteria, protozoa and viruses that cause disease. The number and types of pathogens in manure varies with animal species, age class, feed source, herd health, and the characteristics of manure and the way it is handled, stored and applied. Pathogen survival rates vary significantly depending on the type of organism. For example, some types of pathogens can survive for long periods of time in manure. Some are highly susceptible to UV light exposure,

extreme temperatures and manure treatment. Fecal pathogens, such as Giardia, Cryptosporidia, and some types of E. coli can live in and move with water. Consequently, efforts to control pathogens require multiple management interventions.

The greatest risk of pathogen transfer to surface waters is through runoff leaving farm facilities and fields. Practices that control runoff from manured areas will have the largest impact on reductions in pathogen delivery to water bodies. The steep slopes, highly erodible soils, and many drainages and streams characteristic of north coast watersheds can make it very challenging to manage storm-related runoff. However, researchers from the University of California found that locating livestock heavy use areas on level ground, removing animals from lots during winter months, mulching and seeding these areas prior to the rainy season, and installing vegetated buffer strips to filter runoff can significantly reduce fecal coliform bacteria concentrations and loading rates to drainages and streams (Lewis et al. 2009).

**BMPs designed to prevent pathogens from entering surface water generally include:**

- Biological treatments of manure, such as composting, anaerobic storage, UV light exposure and proper timing of land application.
- Intercepting or filtering pathogens before they reach surface water.
- Use of loafing barns during the wettest times of the year.
- Restricting livestock access to drainages and stream corridors.

**SEDIMENT**

Excessive sedimentation of ponds, streams, and coastal bays degrades water quality and habitat for aquatic organ-



An example of a poorly designed and maintained road. Note the close proximity to the stream, the rill erosion occurring on the road and the un-graveled muddy surface. If this road were outsloped the water would sheet across the road into the stream channel rather than run down the road causing rill erosion.

isms. Excess sedimentation can also dramatically affect drainage patterns and hydrologic processes and functions. Sediment leaving dairy farms and livestock operations can carry phosphorus, nitrogen, and other pollutants chemically bound to eroded soil particles. The high density of animals coupled with high intensity animal traffic to and from milking parlors, holding areas, and pasture can cause significant erosion problems on dairy farms, particularly those located in areas with steep slopes and highly erodible soils.

The erosion, transport and deposition of soil particles are largely controlled by the velocity and volume of water. In locations where runoff is concentrated and allowed to flow rapidly, erosion and sediment transport result. Where runoff is dispersed, or when its velocity is reduced, sediment is deposited. Although erosion is a natural process, land use activities that

compact or disturb soil or remove vegetation can greatly accelerate it. There are several different types of erosional processes:

### **Rill Erosion**

Rills are most visible on unpaved road surfaces or bare slopes. Rills are the many small channels cut by water as it moves downhill on bare soil. If left untreated, rills can become large ruts and washouts. Maintaining adequate vegetation on slopes is the best way to prevent or treat areas subject to rill erosion. Rill erosion on unsurfaced roads and livestock trails is a sign of surface drainage problems. Erosion from these areas can contribute significant quantities of sediment each year to surface waterbodies. Road surfaces subject to rill erosion can be modified through grading to reduce or eliminate the problem.

### **Sheet Erosion**

Sheet erosion is harder to see on the land. It occurs when water sheet flows off the land, carrying a thin layer of soil with it. Sheet erosion is also caused by a lack of adequate vegetation, soil compaction, or soil crusting. Clay soils are highly susceptible to both soil compaction and soil crusting. The easiest way to prevent sheet erosion is through grazing management practices that leave adequate vegetation on pastures during the winter months.

### **Gully Erosion**

Gullies are the most obvious sign of erosion on the landscape and can be the most expensive to control and treat once formed. Animal trails and roads, if poorly sited, can result in gully formation. Gully headcuts can also develop along unvegetated drainages or stream banks, and if left untreated can quickly move upslope. The best way to avoid gully formation is to minimize vehicular and animal access to steep slopes or unstable areas, and to maintain adequate vegetation on hillside pastures and along drainages and streams.

Farm roads and culverted crossings should be well designed and maintained to prevent headcuts and gully formation.

Agricultural activities such as soil cultivation, overgrazing, and the removal of vegetation can accelerate soil erosion. **BMPs to reduce soil erosion include:**

- Controlling grazing and animal traffic patterns.
- Maintaining adequate vegetation on farm fields.
- Seeding and mulching heavy use areas prior to winter rains.
- Limiting grazing on steep slopes and highly erodible soils, particularly during the rainy season.
- Proper road maintenance.
- Maintaining vegetated filter strips along roads, streams and drainages, and below livestock heavy use areas.
- Restricting livestock access to drainages and stream corridors, particularly during the rainy season.

### **BASIC GUIDELINES FOR ASSESSING GRAZING IMPACTS TO PASTURES**

Water quality regulators in California are becoming increasingly concerned with the amount of agricultural nonpoint pollution leaving grazed land. New regulatory programs are being adopted that will require all grazing operations, including pasture-based dairy farms, to prepare ranch water quality management plans. The principles and practices underlying grazing land assessments and ranch plan formulation are very similar to what is currently required for managing pollutants on dairy facilities. In effect, this new regulatory program will require adoption of BMPs to prevent nutrients, sediment, and pathogens from leaving your pastures and silage fields.

Grazing BMPs are management practices that control the season, intensity, frequency and distribution of livestock grazing

in order to enhance forage productivity and protect water quality and other natural resource values. Lactating dairy cattle receive balanced rations and spend much shorter periods of time on pasture than beef cattle. Grazing management decisions on dairy farms are dictated primarily by the animals' milk production cycles, daily milking schedules, and the proximity of pastures to milking parlors and other production areas.

Consequently, traditional range management techniques for determining the number of animals a piece of land can support based on annual forage production rates may not be adequate in guiding pasture usage on a dairy farm. Grazing best management practices for a specific dairy farm will need to be highly tailored to that operation. There are, however, general standards for all grazed land to help prevent soil erosion and to protect water quality.

### **Assessing Pasture Conditions:**

Healthy pastures have ample ground cover throughout the year. Although recommendations vary for different types of grasslands, maintaining 4 to 6 inches of stubble height is a good rule-of-thumb for grasses. When assessing pastures to prioritize management changes to reduce pollutant delivery to surface water, look for visible signs of erosion and overgrazing:

- Are bare soils visible during the rainy season?
- Are there signs of rill or sheet erosion?
- Are gullies, slumps or headcuts present?
- Is there inadequate vegetation on hillslopes or throughout most pastures?
- Are some areas grazed much more heavily than other areas?

Grazing pastures too low during the growing season can retard regrowth, diminish forage productivity, and leave pastures vulnerable to erosion. Maintaining adequate



Well vegetated, fenced off stream that runs through the center of a dairy.

residual dry matter (RDM) on pastures throughout summer and into the fall is important for preventing soil erosion and enhancing the next season's forage growth. RDM is the old plant material from the previous growing season left standing at the start of the new growing season.

Adequate RDM levels (between 800 and 1,200 lbs per acre depending on slope) protects soils from the erosive force of early season rains, slows runoff, and increases infiltration of rainwater. As a rule-of-thumb, the steeper the hill, the more RDM should be left on pasture. Properly managed RDM can enhance soil fertility by increasing soil organic matter and nutrient cycling; it can also enhance the soil seed bank and seed germination (Bartolome et al., 2002).

Livestock access to eroding gullies, drainages, and areas prone to slumping should be restricted. These areas should be revegetated where possible, and grazing should be avoided or used only under a carefully managed restorative grazing program. If animals are overgrazing pastures, infrastructure, such as fencing and water developments, may be needed to allow for greater control over animal distribution and pasture use. Rotational grazing practices that utilize smaller pastures are

often well suited for dairy operations. Sacrifice areas where animals congregate to rest, receive supplemental feed, or drink should be managed to reduce pollutant movement to surface water. Sacrifice areas should be limited in size, and located on level ground away from streams and seasonal drainages.

### **Assessing Seasonal Drainages and Stream Corridors:**

Seasonal drainages and stream corridors should be well vegetated with ample groundcover and woody vegetation. Impacts from livestock should be limited and confined to brief seasonal use for vegetation management purposes only. When assessing seasonal drainages and stream corridors, look for signs of erosion, lack of vegetation and potential livestock impacts:

- Are stream banks unstable or eroding?
- Is bare soil visible along stream banks or seasonal drainages?
- Is the stream exposed to full sun for much of its extent?
- Are feeding, salting, or watering areas located near a stream or drainage?
- Do livestock congregate in stream areas?
- Are livestock crossings stable?
- Are thick mats of algal growth present in the stream?
- Is manure present in or on the banks of streams or seasonal drainages?

Livestock should have limited access to stream corridors. If animals are congregating in stream areas, fencing should be installed and alternative water sources and shade provided elsewhere. Riparian pastures can be developed that allow animals to graze along stream areas for limited periods of time to harvest forage and reduce mulch build-up. Riparian pastures are typically grazed for a few days in mid- to late summer.



Animal trampling of stream banks is one source of erosion in north coast watersheds. If stream banks are eroding, it may be necessary to seek assistance for stream bank restoration. Stream crossings for livestock should be designed to minimize soil disturbance. A low cost solution is to harden the approaches on either side of the stream. Plants such as sedges and rushes are also helpful in stabilizing areas around stream crossings.

### **Assessing Ranch Roads and Animal Trails:**

Unsurfaced roads and animal trails can be significant sources of sediment. They can also concentrate storm-water runoff and act as conduits for pollutant movement to drainages and streams. When assessing ranch roads and animal trails look for visible signs of erosion and any direct pathways for pollutant movement to watercourses:

- Are rills, ruts or washouts present along roads or trails?
- Are culverts or ditches causing gullies to form?
- Are land slumps or headcuts forming upslope or downslope of roads or trails?
- Does sediment fill drainage ditches during winter rains?
- Do roads or trails form pathways from livestock congregation areas to drainages or streams?

Unsurfaced ranch roads should be graded to prevent concentrated flows of stormwater runoff. The longer water flows along a road surface or trail, the more likely it is to form rills and washouts. Road surfaces should be graded to minimize the distance water flows along the surface, and diverted as sheet flow to a well-vegetated area or to a protected outlet. Outsloping, water bars and rolling dips can help divert water from the road surface. Seasonal roads can be seeded with a grass mixture to provide additional erosion control for the winter months. Culverts and ditches should be monitored and maintained to prevent drainage problems.

Livestock movement to and from milk parlors, feeding areas and pastures can have a significant impact on surrounding soils and vegetation. In coastal watersheds, this concentrated movement of animals can cause significant erosion problems, particularly when animals are traveling up and down steep slopes on a daily basis. Designated animal trails or walkways should be established to guide daily animal movements. A minimum width of 12 feet for walkways is recommended for dairy cattle (USDA NRCS, 2009).

Animal trails or walkways should be sited to minimize impacts to highly erodible soils and sensitive ecological areas such as drainages and streams. If animals need to cross small drainages or streams on a daily basis, culverts or bridges can be installed to minimize impacts to both stream banks and water quality. Fencing is recommended to keep animals confined to the trail or walkway if feasible. In addition, a vegetated buffer should be maintained between the walkway and any drainage or stream.

### **BMPS FOR CONTROLLING STORMWATER RUNOFF AND MINIMIZING POLLUTANT LOADS IN AND AROUND DAIRY FACILITIES AND PRODUCTION AREAS**

Regardless of how well a dairy is managed, there will be times when runoff occurs. The North Coast Regional Water Quality Control Board requires that dairies retain all wastewater on site, including runoff from manured areas. The only exception to this rule is in the event of a 25-year, 24-hour (or greater) storm. One way to begin to have a clear understanding of how storm-related runoff flows through your dairy is to look at a topographical map of the property, and draw in facilities and production areas, field boundaries, drainages, roads and animal pathways. Visual assessments during or just after storm events can help you identify high-risk areas and prioritize management changes to reduce agricultural nonpoint sources of pollution that may be leaving your operation.

Managing storm-related runoff can be a daunting task, particularly if dairy facilities and production areas are located at the base of steep hills or bordered by seasonal drainage channels and streams. The first step in managing runoff is to minimize the amount of water flowing through the dairy facility. There are numerous easy to install ways to do this, from installing gutters on roofs and properly sized storm water diversions in and around facilities, to adopting grazing management practices that leave adequate vegetation on hillslopes above facilities to slow runoff and promote infiltration into the soil.

There are also a number of simple management practices that can be adopted to prevent stormwater runoff from coming into contact with manured areas. For example, covering manure stockpiles and keeping slabs and open lots scraped clean prior to storms can significantly reduce the amount of contaminated runoff that needs to be managed. Installing vegetated filter strips around facilities, manure storage areas, and open lots can also significantly reduce pollutant loads, and costs very little to implement.

**Minimize the amount of runoff you are managing by installing clean water diversions in and around dairy facilities and production areas.**

The first step in reducing agricultural nonpoint source pollution is to prevent or minimize the likelihood of clean runoff coming into contact with manured areas.

Berms, diversion ditches and surface drains can be used to capture and divert upslope runoff away from manure stockpiles, open lots and dairy facilities. Diversion ditches should be planted with dense grass to slow water flow and promote percolation into the soil. Energy dissipaters such as rock check dams can be installed if the ditch runs downhill and carries high velocity flows. Keeping hillslopes above facilities well-vegetated will increase water infiltration rates, and help reduce stormwater runoff.

Gutters and downspouts should be installed on all buildings where rooftop runoff can drain to manured areas. This will allow rooftop runoff to be captured and diverted away from open lots and other manured areas. Outlets should be sited to discharge water to well-vegetated areas, stock ponds or other water catchment structures for later use. Vegetated swales and energy dissipaters can be constructed below outlets to reduce the potential for erosion if water is being diverted into pastures or drainages.

**Identify least cost management options for reducing the concentrations of pollutants in stormwater runoff.**

Rain water that falls directly on surfaces in and around facilities and production areas needs to be controlled and diverted to an appropriate manure storage structure or well vegetated area if it comes into contact with manure. The simplest way to reduce contaminated runoff from these areas is to remove animals during the rainy season, if feasible, and scrape clean all slabs and open lots. Vegetated buffer strips should be installed and maintained around all manured areas to help filter pollutants before they reach a drainage or stream.

**Keep manure stockpiles protected from rain and surface water runoff**

Manure stockpiles should be sited on level ground, away from surface water and out of the path of runoff. Permanent manure stockpiles should be placed on a concrete slab or non-permeable clay base, and covered during the rainy season. All leachate from the pile should be controlled, and diverted either to a manure pond or a well-vegetated area away from drainages and streams.

**Control runoff from slabs**

Runoff from slabs should be controlled and diverted into a manure storage structure. Concrete curbs can be installed to divert contaminated runoff to a proper storage area.

For every 1 inch of rain falling on a 1,000 square foot building, approximately 625 gallons of water is generated. Average annual rainfall of 34 inches will generate 21,250 gallons of water from the same building.

For difficult areas that slope away from a central collection area, a sump may be needed to collect runoff and pump it to a manure storage structure. Another alternative is to remove animals from these areas during the rainy season and scrape the slab clean before the first rains.

### Winterize open lots

Livestock confinement areas in and around milk production facilities, such as loafing and feeding areas, exercise lots and sick pens, are typical features of North Coast dairies. Though critical to the daily dairy operation, they also have a high potential for pollutant loading to streams and other surface waters, particularly when used during winter months. A study conducted by University of California researchers linking on-farm dairy management practices to storm-flow fecal coliform loading on ten coastal dairies and ranches found that these areas have the potential to deliver as much as ten-fold more bacteria, nutrients and sediment to surface waters when compared to potential loadings from silage fields and pastures (Lewis et al. 2005).

In response to these findings, additional studies were conducted to identify best practices for reducing potential loads from these areas and to quantify potential load reductions. The study found that winter removal of animals in conjunction with mulching and seeding resulted in a ten-fold reduction in fecal coliform concentrations in runoff compared to untreated sites (Lennox et al. 2007). The study also found that concentrations of suspended solids in runoff from treated sites were one-third to one-half less than from untreated sites. Specific guidelines for treating areas of concern can be obtained from the University of California Cooperative Extension, ANR Publication 8210.

Seeding livestock heavy use areas with grasses such as annual barley and rye in combination with mulching just prior to the rainy season—mid-October to early November—can significantly reduce concentrations of

bacteria, nutrients and sediment in runoff from these sites. This practice is recommended for areas where:

- Livestock are concentrated either seasonally or year-round
- Vegetation is deficient and incapable of controlling soil erosion
- Storm-generated runoff has a pathway to drainages and streams

Open lots should be scraped prior to winter rains, and animals removed for the winter if feasible.

### **Install vegetated filter strips around facilities and manure storage areas, downslope of open lots, at the boundaries of silage fields or pastures receiving land applications of manure, and along drainages and streams to help filter pollutants.**

Vegetated filter strips are simply small areas or strips of land in permanent vegetation, strategically placed to mitigate the movement of nutrients, sediment, and pathogens. They function in numerous ways to reduce pollutant loading to surface water, and are relatively inexpensive to implement. Filter strips slow water runoff, enhance infiltration, and can improve water quality by removing or reducing pollutants in runoff.

The effectiveness of a vegetated filter strip (its pollutant removal efficiency) is determined by factors such as the width of the filter area, the slope of the area, the velocity and volume of water it is receiving, the type of vegetation planted, and the type of pollutant to be mitigated. Strategic places to install filter strips include downslope of livestock heavy use areas, around manure storage areas, at the base of silage fields and pastures that receive manure applications, and bordering drainages and streams.

A well-designed and strategically placed vegetated filter strip can achieve substantial pollutant removal efficiencies:

- Up to 50 percent or more for nutrients.

- Up to 60 percent or more for certain pathogens.
- Up to 75 percent or more for sediment.

**Design Considerations:**

The slope and width of the filter strip have the greatest bearing on removal efficiency rates for all pollutants. Filter strips are not effective on steep terrain or in areas that receive concentrated flows (Grismer et al. 2006). In most cases, the wider the filter strip, the more effective it is at pollutant removal. USDA NRCS Standards and Specifications (No. 393) for designing buffer widths are:

Slope	Minimum Width
1-3%	25 ft
4-7%	35 ft
8-10%	50 ft

Plant selection should be based on local growing conditions. In general, a dense mix of grasses and sedges work best at trapping sediment. Legumes such as clover and vetch can be interseeded to increase soil fertility. In wet areas, sedges and rushes, or perennial grasses that tolerate saturated soil conditions can be used.

**Maintenance Considerations:**

Filter strips should be monitored and excess sediment removed, or the strip should be re-seeded if needed. Noxious weeds should be controlled, and the filter strip can be seasonally grazed to manage vegetation and remove excess nutrients. The annual maintenance or harvesting of filter strip vegetation is recommended to promote future plant productivity. Increased plant growth will result in increased nutrient uptake. Structural mechanisms are also improved by this maintenance by encouraging more consistent cover than is provided by vegetation that is allowed to have many years of thatch accumulation.

**BMPS FOR GRAZING SENSITIVE AREAS**

Vegetation is the most important indicator for assessing pasture conditions. Maintaining ample vegetation on pastures and along drainages and streams is the best defense against all types of soil erosion, and is an important factor in reducing nutrient and pathogen delivery to surface water. Vegetation slows runoff, promotes water infiltration into the soil, and filters pollutants before they reach watercourses.

Not all of the BMPs presented in this section will be necessary or appropriate for every operation. For example, installing fences along streams is a frequently cited management recommendation for protecting water quality, but if livestock do not congregate in these areas and there is ample groundcover and woody vegetation, it may not be necessary to invest in fencing. The condition of the land should dictate where you invest your time and resources.

**Riparian Pastures**

Riparian pastures include the floodplain adjacent to the creek, and should be fenced to control animal access if impacts are evident. Riparian pastures should be grazed, but both the season and intensity of use should be managed to maintain healthy vegetation and stable stream banks. Off-stream water should be provided in the pasture so that the cattle do not need to enter the stream for drinking water.

Season of use and grazing intensity are critical aspects of proper grazing of riparian pastures and buffer strips. Grazing should occur when the soils are dry enough to withstand animal impact, and animals should be removed before the end of the growing season so that vegetation can recover and bare areas can be revegetated.

Grazing intensity controls the level of forage left in the pasture after the cattle are removed. Maintaining adequate vegetation on pastures through the summer and into the

fall is important for preventing soil erosion and enhancing the next season's growth. Grazing that is too intensive can retard regrowth, diminish forage productivity, and leave pastures vulnerable to erosion. Grazing with large numbers of animals for shorter periods of time is generally preferred to more lengthy grazing periods with fewer animals.

Livestock can be used as a vegetation management tool to achieve riparian goals. Revegetating a riparian area with woody plants may require planting trees, and usually requires complete animal exclusion from the stream banks for a year or two. Most trees, especially willows, can survive an occasional light browsing. Grazing the riparian zone in the spring when the grass is most attractive to livestock will limit browsing of trees and shrubs. A waterway that is choked with woody vegetation may be grazed in summer to open up the stream.

### **Hillside Pastures**

Two basic factors affect surface erosion on grazed hillsides: vegetative groundcover and cow traffic patterns. Sufficient vegetative groundcover can help prevent erosion. Groundcover or RDM estimates should be made before the end of the growing season. This allows for livestock to be removed from an area that needs higher RDM levels. When the cows are removed before the end of the growing season, time remains for grass regrowth and the accumulation of more RDM.

RDM levels that are well above target can be reduced by grazing at the end of the growing season and in the summer. It is also important to maintain sufficient groundcover in the winter and early spring. Allowing grass to grow up to about a foot tall and then grazing it to no lower than 4 inches is recommended in the beginning of the season when soil is wet. This will help to prevent soil erosion and soil compaction.

Cows in large, continuously grazed pastures tend to use the same paths every day. These paths can capture runoff

during the winter rainy season and develop into gullies. Path locations are usually influenced by the placement of water troughs, fences and gateways. Experience, as well as trial and error, is often needed to alleviate problems created by cow paths. Relocating fence lines and water troughs can be expensive, so careful planning is recommended.

When fencing out an actively eroding area on a hillside it is best to think big. Fence well beyond the affected area and try to place the new fence on a gentler slope. Remember that the affected area inside the new fence will still be grazed, just not as often and when the ground is firmer and the grass longer. Fences provide more animal control to regulate grazing intensity and duration, and new fence can also alter the traffic patterns in the pasture.

Management-intensive grazing systems require large pastures to be subdivided into smaller pastures with either temporary or permanent fencing. This will usually require the addition of watering points to alleviate the need for long cow paths across hillsides. A larger number of smaller paddocks gives the operator control of forage intake and pasture recovery times. If pastures are used for milking cows, a narrow road will be needed between the pastures and the milking parlor. These roads are constructed similarly to other farm lanes but can be much narrower if they are only for cow and ATV use. The costs of additional water development, fencing, and lanes can be offset by improved animal and pasture performance.

### **BMPS FOR REDUCING EROSION FROM RANCH ROADS**

Ranch roads are necessary for many farming operations. The steep terrain and high rainfall of the North Coast create a huge potential for sediment production from unpaved roads. The first step to reducing erosion and sediment delivery from roads is to outline your transportation needs, specifying the type, seasonality and amount of use each road is



Grazing terraces caused by cattle traversing hillsides.

likely to receive. This practice will help when determining what erosion control measures are necessary for each road.

The most obvious strategy for preventing road-related sediment from entering streams and other waterways is to locate the road away from any stream. Roads should follow contours, so that runoff can drain from the road in a dispersed fashion. If the road has to parallel a stream, there should be a minimum vegetated buffer of 6–10 feet in width to allow runoff to slow down, deposit sediment, and infiltrate the soil before it can reach the stream.

### **Outsloping, rolling dips and ditch relief culverts**

Traditionally, roads have been constructed with an insloped shape and an inboard ditch. Such roads basically act as

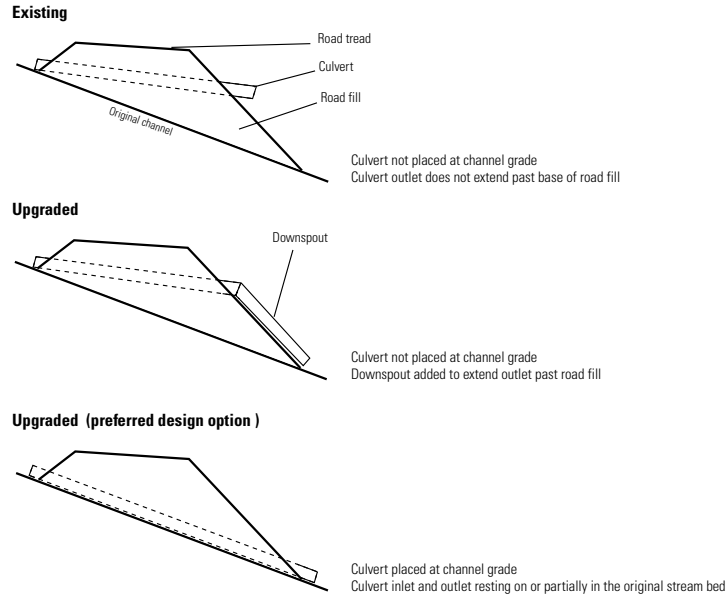
stream channels that run across the slope – not the way natural streams work. When siting a road or cow lane, always observe the original (natural) flow of water across the landscape, where surface runoff would flow if no road existed. A properly constructed and maintained road will not alter the original flow of water. A gentle outslope functions to sheet water off of the road without causing erosion.

The grade of the outslope depends on the steepness of the road – the steeper the road, the steeper the outslope should be, to ensure that water flows off the road instead of staying on it. Outslopes of between 4 and 10% are effective at dispersing runoff on most slopes. Outsloping can be defeated by ruts in the road, so it should be combined with rolling dips to avoid the concentration of runoff (see figure at right). Most importantly, outsloped roads generally require no inboard ditch, which eliminates the need for culverts to convey runoff across the road via culverts, and fewer culverts equals less maintenance.

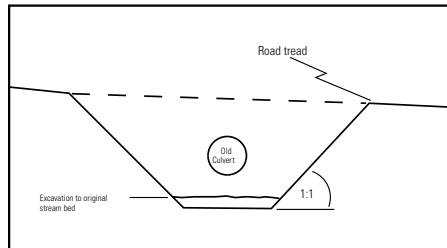
Rolling dips are constructed at intervals to drain the road surface, and can be constructed with or without outsloping, although they are more effective and easier to construct on an outsloped road. They should be spaced closely enough so that runoff does not accumulate at the rolling dip outlet in quantities that could cause an erosion problem. A properly constructed rolling dip reverses grade to ensure that runoff cannot flow past the dip and continue down the road. Rolling dips should also have some outslope through the dip axis so that water is forced to flow off the road.

If the slope is wet and has springs, it can be a better practice to retain an inboard ditch to prevent the road from becoming saturated. Ditch relief culverts should be used to drain the ditch frequently, again so that runoff is not delivered to the outboard side of the road in quantities that could cause an erosion problem. And ditch relief culverts should be installed with at least a 10% slope, to ensure that they never plug.

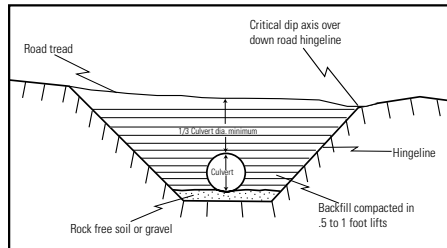
**TYPICAL DESIGN OF NON-FISH BEARING CULVERTED STREAM CROSSINGS**



Excavation in preparation for upgrading culverted stream crossing



Upgraded stream crossing culvert installation



Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100 year flood flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

**Stream crossing culvert installation**

- 1) Culverts shall be aligned with natural stream channels to ensure proper function, prevent bank erosion and debris plugging problems.
- 2) Culverts shall be placed at the base of the fill and at the grade of the original streambed or downspouted past the base of the fill.
- 3) Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
- 4) Culvert beds shall be composed of rock free soil or gravel, evenly distributed under the length of the pipe.
- 5) To allow for sagging after burial, a camber shall be between 1.5 to 3 inches per 10 feet culvert pipe length.
- 6) Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
- 7) One end of the culvert pipe shall be covered then the other end. Once the ends have been secured, the center will be covered.
  - Base and side wall material will be compacted before the pipe is placed in its bed.
  - Backfill compacting will be done in 0.5- 1 ft lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
- 9) Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.

- 10) Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
- 11) Layers of fill will be pushed over the crossing until the final, design road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

**Erosion control measures for culvert replacement**

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures that are implemented will be evaluated on a site by site basis. Erosion control measures that may be employed include but are not limited to:

- 1) Minimizing soil exposure by limiting excavation areas and heavy equipment disturbance.
- 2) Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
- 3) Retaining rooted trees and shrubs at the base of the fill as “anchor” for the fill and filter windrows.
- 4) Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring and/or benching prior to the first fall rains.
- 5) Extra or unusable soil will be stored in long term spoils disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential or proximity to a watercourse.
- 6) On running streams water will be pumped or diverted past the crossing and into the down stream channel during the construction process.
- 7) Straw bales and/or silt fencing will be employed where necessary to control runoff within the construction zone.



Road with an upgraded culvert, sized so that even during high storm flows water will pass through the culvert instead of diverting around the culvert causing erosion.

### **Stream crossing culverts and other structures**

A culvert or other appropriate structure should be placed at any location where the road crosses a stream or ephemeral drainage. A stream crossing culvert should be sized to convey a 100-year storm flow. Undersized culverts may not have the capacity to convey streamflow during large storms, causing water to back up and potentially divert over the road or down the ditch. Common mistakes in culvert installation include placing the culvert too high in the road fill to minimize the length of pipe required, and placing the culvert so that it discharges away from the natural stream channel. Stream crossing culverts should be installed at the base of the road fill, to continue the natural grade of the stream channel and prevent sediment deposition inside the culvert.

Culverts should also be placed in the axis of the stream channel to minimize erosion around the culvert outlet.

Armored fill crossings (wet crossings) are low-maintenance alternatives to culverts. An armored fill is basically a rolling dip that has been armored with riprap or lined with concrete to protect the road fill from streamflow. A road design professional should be consulted before an armored fill is constructed, because both the design and rock size are critical to avoiding erosion.

### **Road surfacing**

A road used in all seasons will require a rocked surface. This will decrease the amount of sediment produced during the winter, and will also reduce the effort and cost to maintain the road. The type of rock used to surface the road should be selected based on local soil conditions. Seasonal roads can be reseeded and mulched before the rainy season just like cow exercise lots.

### **Road maintenance**

Road maintenance should include inspection of all culverts before the start of the rainy season, and again after large storms. Roads that are properly drained with outsloping and rolling dips require less frequent maintenance, but periodic grading is usually necessary. When grading, be sure to maintain reverse grade and outslope on rolling dips to ensure proper drainage. On outsloped sections of road, light grading may be needed to remove ruts, and the outside shoulder of the road should be graded at a slightly steeper outslope, so that water sheeting off the road deposits its sediment away from the road shoulder.



## REFERENCES

Bartolome, J.W., W.E. Frost, N.K. McDougald and M. Connor. 2002. *Guidelines for Residual Dry Matter (RDM) Management on Coastal and Foothill Rangelands in California*. University of California Division of Agriculture and Natural Resources, Publication 8092.

California Plant Health Association. 2002. *Western Fertilizer Handbook*, Ninth Edition. CPHA, Sacramento, CA.

Cogger, C.G., T.N. Cramer, A.I. Bary, and D.C. Grusenmeyer. Whole Farm Nutrient Flow and Manure Management. Presented at Northwest Dairy Shortcourse, Blaine, WA. January 1999.

Ebeling, A.M., L.G. Bundy, T.W. Andraski, and J.M. Powell. 2002. Dairy Diet Phosphorus Effects on Phosphorus Losses in Runoff from Land-applied Manure. *Soil Science of America Journal* 66:284-291.

Gold Ridge Resource Conservation District. *Manure Management: A Publication of Agricultural Producers in Marin and Sonoma Counties*, Final Issue, June 1996. Funded by the North Coast Regional Water Quality Control Board, EPA Clean Water Grant Funding, Sebastopol, CA.

Godwin, D. and J.A. Moore. 1997. *Manure Management in Small Farm Livestock Operations: Protecting surface and groundwater*. Oregon State University Extension Service.

Grismer, M.E., A.T. O'Geen, and D. Lewis. 2006. *Vegetative Filter Strips for Nonpoint Source Pollution Control in Agriculture*. University of California Division of Agriculture and Natural Resources, Publication 8195.

Hart, J., M. Gangwer, M. Graham, and E.S. Marx. 1997. *Dairy Manure as a Fertilizer Source*. Oregon State University Extension Service.

Humboldt County Resource Conservation District. *Dairy Water Quality Field Guide*. Eureka, CA.

Kelling, K., L. G. Bundy and A Ebeling. 2003. *Management Options for Farms with High Soil Test Phosphorus Levels*. Nutrient and Pest Management Program, University of Wisconsin-Madison. Report 1-07-03-5M.

Kinsey, N. and C. Walters. 2006. *Hands-on Agronomy: Understanding Soil Fertility & Fertilizer Use*. Acres U.S.A., Austin, TX.

- Koelsch, R. Whole Farm Nutrient Planning. Livestock and Poultry Environmental Stewardship Curriculum. LEPS Website, [www.lpes.org](http://www.lpes.org).
- Lennox, M.S., D.J. Lewis, J. Gustafson, K.W. Tate and E.R. Atwill. 2007. Water Quality Treatment for Livestock Feeding and Exercise Areas on California Coastal Dairy Farms and Ranches. University of California Division of Agriculture and Natural Resources, Publication 8210.
- Lewis, D.J. et al. 2009. Reducing Microbial Contamination in Storm Runoff from High Use Areas on California Coastal Dairies. *Water Science & Technology*, in press.
- Lewis, D.J. et al. 2009. Management of Microbial Contamination in Storm Runoff from California Coastal Dairy Pastures. *Need Journal Name*.
- Lewis, D.J., R. Atwill, M.S. Lennox, L. Hou, B. Karle and K.W. Tate. 2005. Linking On-farm Dairy Management To Storm-flow Fecal Coliform Loading for California Watersheds. *Environmental Monitoring and Assessment* 107: 407-425.
- Lorimor, J., W. Powers and A. Sutton. 2000. Manure Characteristics. MWPS-18 Section 1. Midwest Plain Service, Ames, IA.
- Madison, F., K. Kelling, L. Massie, and L.W. Good. Guidelines for Applying Manure to Cropland and Pastures in Wisconsin. University of Wisconsin-Extension publication A3392.
- Marin Resource Conservation District. Date. Groundwork: A Handbook for Small-scale Erosion Control in Coastal California, Second Edition.
- Meyer, D. and D. Mullinax. 1997. Nutrient Content of Dairy Manure. University of California Cooperative Extension Dairy Manure Management Series, UCCE-DMMS-3.
- Meyer, R.D. and K. Andersen, undated. Nitrogen Management on Pastures for Dairies. A PowerPoint Presentation.
- Meyer D. and J. Menke. How to Improve Your Preliminary Dairy Facility Assessment Ratio. University of California, Division of Agriculture and Natural Resources—Publication 8283.
- Morse, D. and A. Wubishet. 1996. Dairy Manure Utilization. University of California Cooperative Extension Dairy Manure Management Series, UCCE-DMMS-7.
- National Research Council (NRC). 2001. Nutrient Requirements of Dairy Cattle. Seventh Revised Edition. National Academy Press, Washington, D.C.
- Powell, J.M., D.B. Jackson-Smith, L.D. Satter and L.G. Bundy. 2002. Whole-Farm Phosphorus Management on Dairy Farms. Wisconsin Fertilizer Aglime and Pest Management Conference, January 17, 2002.
- Schulte, E., L. Walsh, K. Kelling, L. Bundy, W. Bland, R. Wolkowski, J. Peters, and S. Sturgul. 2005. Management of Wisconsin Soils, Fifth Edition. Cooperative Extension Publications, University of Wisconsin-Extension. Madison, WI.
- Singer, M.J. and D. N. Munns. 2002. Soils: An Introduction, Fifth Edition. Prentice Hall, Upper Saddle River, NJ.
- Spiels, M. and S. Goyal. 2007. Best Management Practices for Pathogen Control in Manure Management Systems. Cooperative Extension Publications, University of Wisconsin-Extension. Madison, WI.
- Stallings, C.C., Katherine F. Knowlton, 2005. Strategies to Reduce Amounts of Nitrogen and Phosphorus in Dairy Rations. Va Coop. Ext. Dairy Guideline, Publication No. 404-130.

Sturgul, S.J. and L.G. Bundy. 2004. Understanding Soil Phosphorus. University of Wisconsin-Extension publication A3771.

Sullivan, P. 2004. Sustainable Soil Management. ATTRA. Available online at <http://attra.ncat.org/attra-pub/PDF/soilmgmt.pdf>

USDA NRCS. 2001. USDA Natural Resources Conservation Service. Conservation Practice Standard, Nutrient Management, CODE 590, Part 402. NRCS, Washington, DC.

USDA NRCS. 2002. USDA Natural Resources Conservation Service. Conservation Practice Standard, Prescribed Grazing, CODE 528A. NRCS, Washington, DC.

USDA NRCS. 2003. USDA Natural Resources Conservation Service. Conservation Practice Standard, Heavy Use Area Protection, CODE 561. NRCS, Washington, DC.

USDA NRCS. 2009. USDA Natural Resources Conservation Service. Conservation Practice Standard, Animal Trails and Walkways, CODE 575. NRCS, Washington, DC.

Van Eenennaam, A. 1997. Planning and Designing Dairy Waste Storage Facilities. University of California Cooperative Extension Dairy Manure Management Series, UCCE-DMMS-2.

Van Eenennaam, A. 1997. Dairy Manure as a Soil Amendment. University of California Cooperative Extension Dairy Manure Management Series, UCCE-DMMS-6.

Zimmer, G. F. 2000. The Biological Farmer: A Complete Guide to the Sustainable & Profitable Biological System of Farming. Acres U.S.A., Austin, TX.



## APPENDIX A

# SOIL SAMPLING GUIDELINES

## SOIL SAMPLING AND MAPPING

The key to effective soil sampling is getting a representative sample from each pasture or silage field. The best way to begin is with a soils map of the dairy. Contact your USDA NRCS District Field Office, Western United Dairymen Environmental Services Division, your local Resource Conservation District or Cooperative Extension office to obtain a soils map for your property.

Pasture and silage field boundaries should be drawn on the map and given a field code. Some fields will contain more than one soil type, and some soil types will cover more than one field. If more than one soil type dominates large areas of an individual field, you may want to treat it as two fields, collecting and submitting samples for each. Soil texture can have dramatic effects on nutrient reserves in soil. When you receive your soil analysis report, make sure to refer back to your soils map to investigate any striking differences in results.

Using your soils map, or your own best judgment, collect “subsamples” from within each management area and thoroughly mix them into a composite sample. Then take a single two-cup sample from the composite sample, and place it in an individual sampling bag, marked with a unique identi-

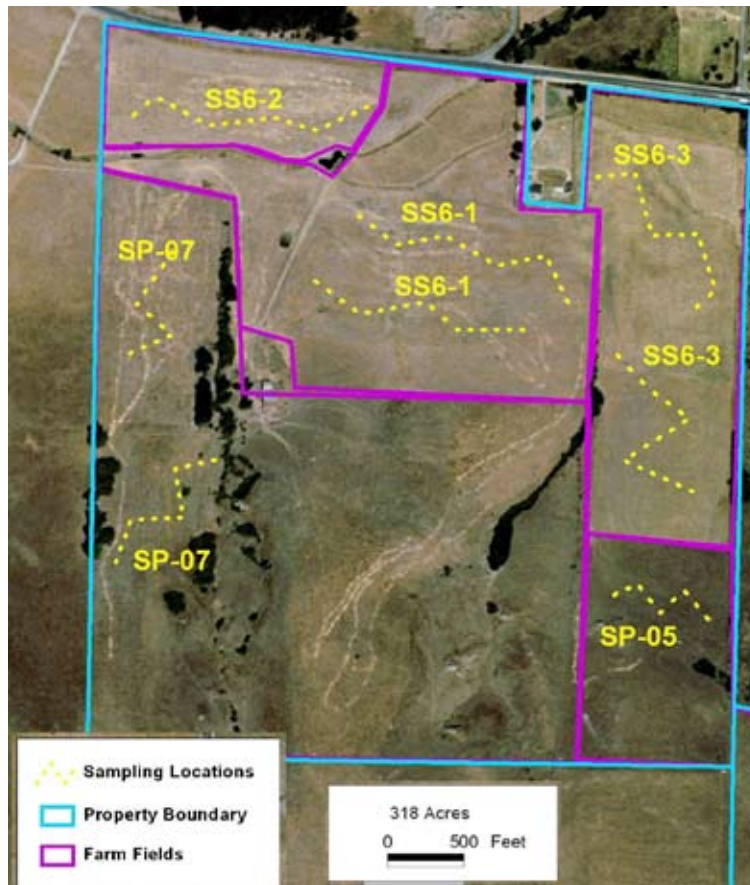
fying code. Mark the code on the map to remind you where the composite sample was gathered from (see graphic below). When you receive your soil sampling results, you will have results for each of your management areas (fields). The results will assist you in making future decisions about where and how much manure fertilizer, or other amendments you should be applying. The most important changes to note would be those in crop yield production or forage quality.

## SOIL SAMPLING TIMING

Soil test results can vary depending on the time of year the sample was collected. Samples collected just after a crop harvest will be different than if the sample was collected at the beginning of the growing season or soon after a manure application. For monitoring soils you should sample at the same time of year, every 3 to 5 years. If you are sampling your soils as a diagnostic to determine excesses or deficiencies, you should sample in spring when plants are growing. Soils can be re-sampled a year or two later to determine if amendments were useful in correcting soil imbalances.

Some nutrient deficiencies in soils that effect yield production or quality are best diagnosed with plant tissue sampling.

This is an example of a soils sampling map. Note that the subsamples for each field were taken in a zigzag pattern.



Refer to your County Soil Survey to get general descriptions of soil types found on your property. Your local NRCS or RCD office should have a copy or you can find it online here: [http://soils.usda.gov/survey/online\\_surveys/california](http://soils.usda.gov/survey/online_surveys/california).

**Soil Sampling – Field Composite Method (USDA NRCS, Petaluma Field Office)**

The following soil sampling procedure is for field scale soil tests to determine soil nutrient content to calculate manure application rates.

1. Obtain a soils map and an aerial photo of your property.
2. Outline each field on the map and label it.

3. Determine the recommended number of samples from each uniform soil area (Table A.1).

**TABLE A.1 RECOMMENDED NUMBER OF SUBSAMPLES BASED ON UNIFORM SOIL OR VEGETATION.**

Area (acres)	Number of Subsamples
Fewer than 5	15
5 - 10	18
10-25	20
25-50	25
More than 50	30

4. Collect subsamples from one area at a time and thoroughly mix in a bucket before extracting a small sample (about two cups) and placing it in a sealed bag marked with your name, the date, and the unique soil or field code. Avoid taking samples from livestock heavy use areas (trails, or loafing and feeding areas). Areas that differ in slope by greater than 2%, show a notable change in vegetation, or change in soil type as visible on the ground or on the soils map should be sampled separately. Remove vegetation down to bare soil at the sample location before taking the sample. For pasture and silage fields sample to a depth of around 6 inches. Repeat for each unique area.
5. Fill out the lab form, if one was provided. Keep sample cool and dry, and send to lab within 24 hours if possible.



Photo 1, cutting an approximate one inch slice of soil from the side of the dug hole about 6 inches deep.



Photo 2, making sure you are getting a true cross section of top 6 inches of soil.



Photo 3, showing a properly retrieved soil sub-sample.

Avoid taking soil samples from areas where cows congregate like the bedding area at top of hill, or along a fence line or trail, and do not take a sample where there is visible manure.



Photo 4, shaving off excess soil so that there is an even ratio of soil represented from all 6 inches of soil sampled.



Photo 5, sub-sample that I will now toss into the bucket to mix with other sub-samples to get my composite sample to place in a bag and send to the lab. The submitted composite sample will be about 2 cups.



Photo 6, mix soil sub-samples in a bucket to prepare sample to send to the lab.





## APPENDIX B

# MANURE SAMPLING GUIDELINES

## How to sample manure (liquid and solid)

### STANDARD MANURE SAMPLING METHODS:

Standard lab analyses will determine the total N, P, K, and other nutrient content of manure. Most agricultural labs report liquid manure results on an as-sampled basis and solid manure on a dry basis. It is highly recommended that you sample soon before manure application. Carefully check the units on the manure test results, as different units are sometimes used. When results are reported on an as-sampled basis, the most common units used are lb/ton for solid manure and either parts per million (ppm), percent, or lb/1000 gal for liquid manures. A section on useful conversions can be found below.

### ALTERNATIVE LIQUID MANURE SAMPLING OPTIONS:

The nutrient quick test is a procedure for in-field measurement of ammonium concentration in dairy lagoon water. This procedure is simple, fast and inexpensive enough to be completed directly before manure application by the operator. The abbreviated and general description of the procedure is as follows, adapted from (M. Campbell Mathews, N.D.). For more specific information please contact your local Cooperative Extension office or the Gold Ridge RCD.

- A syringe is used to accurately dilute a 1cc sample of lagoon water in 200 cc of water.
- A dispersing and mineral stabilization reagent is added to sample.
- Another reagent is added to a subsample and, after the appropriate time for color development, the absorbance is read using a hand-held colorimeter.
- Because lagoon water will not be perfectly clear and may have a color of its own, a reading of the diluted lagoon water is taken prior to adding the sample with the reagent.
- A small amount of toxic waste is produced by each test which must be disposed of at a hazardous waste receiving facility.

If you are interested in using a “Quick Test”, you can obtain your materials, instructions, datasheets, and assistance in using the test by contacting the University of California Cooperative Extension in Stanislaus County at (209) 525-6800. The Gold Ridge RCD also has this equipment available to use for a small fee.

### SOLID MANURE SAMPLING

Lab analyses should include the following:

- % Moisture
- Organic nitrogen
- Nitrate-nitrogen
- Phosphorus
- Potassium
- % Organic matter
- Sample size: Contact your analytical lab prior to sampling to find out appropriate sample volume and whether the samples require special handling, such as refrigeration.
- Take multiple subsamples from below the pile surface down to 18 inches. Take between 4 and 12 subsamples from different locations around the pile. Thoroughly mix the subsamples and extract about a quart to be placed in a lab test container or clean plastic bag. Please check with your lab to obtain specific instruction on mailing procedures as manure samples in inappropriate packaging have the potential to spill or explode. Various sources of solid manure (e.g., corral, separator solids, aged manure, etc.) should be sampled and analyzed separately.

### LIQUID MANURE SAMPLING

Lab analyses should include the following:

- Ammonium
- Total Kjeldahl Nitrogen (TKN)
- Phosphorus (P)
- Potassium (K)
- Sample size: A 16-ounce sample should be sufficient for most nutrient analyses.
- Clean plastic containers can be used for standard nutrient analyses. If you are checking for organic residues or bacteria, a separate sterile container must be used. Please check with your lab to obtain specific instruction on mailing procedures as liquid manure samples may need to be refrigerated,

may have a short shelf life and if shipped in inappropriate packaging have the potential to spill or explode.

- Use Table B.1 below to determine number of samples needed:

TABLE B.1. MANURE SAMPLE PROTOCOL BASED ON STORAGE STRUCTURE		
Storage structure	# of Samples	Reason
Agitated liquid slurries	1	If properly agitated for 2 to 4 hours prior to sampling, one sample should be sufficient. One sample should be taken each time the structure is emptied.
Liquid slurries	3 or more	Several samples are required as solids settle and nutrients tend to stratify in storage. At least three separate samples are needed and should roughly correspond to the top, middle, and bottom portions of the pit or basin.
Manure Pond/Lagoon liquids or multiple stage solids-separation systems	1	Manure ponds or lagoons that act as settling basins or are used in flush systems are usually not agitated. Take one sample just from the top ½ ft. of the liquid at various locations around the lagoon, staying 10 to 15 ft. away from the edge. Avoid surface scum or debris.

*Source: University of Minnesota Cooperative Extension*

- Pond sampling technique:

*Pond sample:*

Use a ½” or ¾”, 8 to 10 ft. PVC pipe. Push the pipe into the liquid, avoiding the bottom foot of the pond. Place a hand over the top opening to seal the pipe, pull up, and empty into a bucket.

## APPENDIX C

# UNDERSTANDING YOUR SOIL ANALYSIS REPORT

A soils report provides a great deal of useful information, including the level of organic matter in the soil, soil nutrient levels, percent cation saturation, soil pH, and recommended application rates for any deficient plant nutrient (soil fertility report). A soils report is an important tool for assessing overall soil fertility on a per field basis. They are most helpful for assessing trends and nutrient ratios (e.g., percent cation saturation) that affect overall soil fertility. A soils report provides a “snapshot” of any nutrient imbalances, deficiencies, or excesses for the specific areas where samples were collected. It is an important tool for comparing conditions in different fields and pastures that may reflect past management decisions or inherent soil characteristics (e.g., soil texture). It also provides a baseline to guide future management decisions.

With this information, it is possible to adjust manure application rates or selectively apply soil amendments such as calcium or sulfur to individual fields as needed. A soils report can also function as a guide for selecting plant species or for investigating why certain plants do not flourish in certain fields. For instance, legumes do not grow well in soils with high magnesium levels. Increasing calcium levels in fields with high magnesium will have the added

benefit of improving growing conditions for clover, which can significantly increase nitrogen levels in the soil.

## SOIL NUTRIENT RESERVES

Plants require 17 essential elements. Three of these, carbon, hydrogen, and oxygen, plants take from air and water. The remaining 14 are typically absorbed from the soil by plant roots, and are divided into three groups: primary nutrients, secondary nutrients, and micronutrients. All of the essential elements are equally important for healthy plant growth and reproduction, though in varying amounts. Plants typically take up more nitrogen and potassium than any other essential element, with the exception of carbon, hydrogen, and oxygen.

The annual nutrient requirements of crops and forages are much less than the total nutrient content of the soil, typically about 0.5 to 2 percent. However, the amount of soil nutrients that are readily available to plants in any year is also only a small fraction of the total nutrient content of the soil, typically from less than 1 percent to over 30 percent (5 percent is a rough average). This is why yearly crop requirements for some nutrients (typically nitrogen) can exceed the amount of soil nutrients in readily available form.

The organic component of soil, though typically less than 5 percent, holds a very high percentage of the soil's nutrient reserves. Over 90 percent of the nitrogen, 15 to 80 percent of the phosphorus, 50 to 70 percent of the sulfur, and some potassium and trace elements are derived from the organic matter in soil (Zimmer, 2000). Organic matter is therefore key to soil fertility and productivity. Typical soils can have several thousand pounds per acre of nitrogen, phosphorus, calcium, magnesium, and sulfur in the upper 6 to 7 inches of the soil, and more than 30,000 pounds per acre of potassium (ibid.).

Usually the lab where you chose to send your samples can provide an easy-to-read explanation of the soil analysis report and for an additional fee the lab can provide specific recommendations. Listed below are some of the important nutrients most often listed in a soil analysis report.

#### **Primary Nutrients (N, P, and K)**

Plants require N, P, and K more than any other nutrients. Often these primary nutrients are reported as nitrate-nitrogen, phosphate and potash, respectively. Nutrients can be reported in various ways depending on the lab. Conversions are listed below with the appropriate nutrients.

#### **Secondary Plant Nutrients (Ca, Mg, and S)**

Plants require calcium, magnesium, and sulfur in lesser amounts than primary nutrients. Calcium and magnesium are essential plant nutrients and can raise soil pH. Sulfur is also an essential plant nutrient but can lower soil pH. Local soils tend to be low in sulfur.

#### **Micronutrients (Zn, Mn, Cu, Fe, B, Cl, and Mo)**

Plants require micronutrients in minimal quantities. Shortages of micronutrients can be hard to detect but when lacking can have large effects on crop yields.

Proper diagnosis of micronutrient levels may require plant tissue sampling and crop yield comparisons.

**Nitrogen (N)** — is found in soil and animal manures in several forms. The largest percentage of N in raw manure is in the organic form and is not directly plant available. Organic N must be mineralized to inorganic forms such as ammonium-N and nitrate-N to become plant available. The amount of organic nitrogen released during each growing season is estimated to be between 2-5% of organic nitrogen reserves (Zimmer, 2000). A soil test showing 5% organic matter will release 100 pounds or more per acre of plant available nitrogen during the growing season.

Forage crops need anywhere between 50-400 pounds or more of plant available nitrogen per acre, depending on yield expectations, plant species composition, and other variables such as the amount of nitrogen fixing legumes in the pasture or silage field. A field with 25% legume cover can supply 200 lbs or more of additional nitrogen per acre to crops and other forage species.

**Organic Matter %** — is the percent by weight of organic matter per sample. Organic matter increases the water holding capacity of soils and can be a major source of nutrients for plants

**Estimated Nitrogen Release (ENR)** — ENR is an estimate of organic matter decomposition and nitrogen release during a growing season.

**Total Kjeldahl Nitrogen (TKN)** - Refers to the total nitrogen in a soil or manure sample. Not all of the nitrogen in a TKN test is readily available; it may take years for all nitrogen to be released.

**Nitrate (NO<sub>3</sub> N)** — Nitrate in a report refers to the readily available sources of nitrogen in a sample. Concentrations in a sample are converted to an equivalent rate of pure nitrogen. This parameter does not refer to the total amount of nitrogen present in the soil.

**Phosphorus (P)** — Available soil phosphorus may be only 1 percent or less of the total phosphorus present in the soil. Most of the total phosphorus in soil is bound up chemically in only slightly soluble compounds. Phosphorus availability is affected by soil pH. In acidic soils, phosphorus is less available to growing plants. Maximum availability of soil phosphorus occurs at a pH level between 6.5 and 7.5. Legumes, such as alfalfa and beans, have a high phosphorus requirement.

Soil phosphorus reserves in farm fields that have consistently received applications of manure will typically have more than adequate levels of phosphorus for most forages and crops. Raising the pH on acidic soils will ensure that enough phosphorus is available for clover and other legumes.

Soil reports deliver information of P present in two ways, either as P or  $PO_5$ . To convert from one to the other refer to the conversions section below.

**Potassium (K)** — Potassium is a cation and is one of four elements (K, Mg, Ca, and Na) that together with any free hydrogen ions determine what is referred to as the calculated Cation Exchange Capacity (CEC).

Most soils that have received consistent applications of manure will have adequate reserves of potassium in the soil. Large amounts of potassium are removed from the soil when vegetation is removed, as with silage and hay. *Excessive levels of potassium in forages and crops can lead to livestock health issues such as milk fever (post-parturient hypocalcemia), or reduced blood calcium levels, which can cause general weakness and lack of appetite in dairy cows.* In addition, soils with potassium levels above 7.5% base saturation are much more likely to have weed problems (Kinsey, 2006).

**Magnesium (Mg)** — Magnesium is an activator of many plant enzymes required for plant growth. Magnesium levels are often excessively high in western soils. A base saturation over 15% reduces crop yields for corn, grasses, wheat,

oats, and barley. Nitrogen fixing legumes such as clovers and alfalfa are even more sensitive to high magnesium levels in soil. A magnesium base saturation of between 10-12% is optimal for growing legumes (ibid.).

**Calcium (Ca)** — Calcium is a nutrient needed at high levels for both plants and beneficial soil organisms. Increasing the amount of calcium in the soil is often key to improving soil fertility. Unlike most other nutrients, the amount of calcium in the soil is usually very close to the amount that is plant-available (Kinsey, 2006). Calcium improves soil structure, enhancing aeration and root growth. Higher calcium levels also increase the availability of other plant nutrients, including nitrogen, by raising soil pH, and can also raise the protein content of plants.

**Sodium (Na)** — Sodium is a key element in sodium chloride, or common salt. If sodium shows up high on your manure or soil tests this could mean you may have salt entering your system through excesses in your cows' diets.

**pH** — pH is an indication of the acidity or alkalinity of your soils or manures. Soil pH affects plant nutrient availability and manure decomposition rates. A soil pH between 6.2 and 6.8 is ideal for pastures, 7.0 is a neutral pH and anything higher than 7.0 may mean soil is alkaline due to excess from salts, or calcium. Soils with a pH that is less than 6.0 have lower potential for plant growth.

**pH Buffer Index** — pH buffer index measures both the active and reserve acidity in soils. The reserves of acidity are not picked up in standard pH tests. Use the following table to estimate lime application needed to achieve desired pH.

**TABLE C.1. TONS/ACRE AGRICULTURAL LIME (70 SCORE) PER 6-INCH DEPTH, ADAPTED FROM "METHODS OF SOIL ANALYSIS" PART 2, ASA (PAGE, MILLER, & KEENEY, 1983).**

Reported Buffer Index	Tons/Acre of Lime Application to reach a pH of 6.5
7.0	None
6.9	0.5
6.8	1.0
6.7	1.5
6.6	2.0
6.5	3.0
6.4	3.5
6.3	4.0
6.2	4.5
6.1	5.0
6.0	6.0

**Sulfate Sulfur (SO<sub>4</sub>)** — Is the measurement of sulfur that is readily available to plants. Other forms of sulfur in the soil become available to plants over a longer period of time with the aid of soil microbes. More sulfur is required by plants than either calcium or magnesium, and sulfur is essential for complete proteins. Sulfur deficiencies affect both yield and quality, including palatability. Adequate supplies of sulfur help seedlings survive in cool, moist soil, and promote rapid root development during early periods of growth.

Organic matter is the major source of sulfur in soil. The higher the organic matter, the more sulfur will be available to growing plants. The minimum amount of sulfur for any soil is between 20-25 ppm, which translates to 40-50 pounds per acre. Additional sulfur is needed if magnesium levels are high. Gypsum contains 16% sulfur, and is therefore a good source where calcium is also needed.

**Conductivity** – Conductivity is the amount of soluble salts and is a crude measurement of ions in soil, manure, or water. Levels of NO<sub>3</sub><sup>+</sup>, K<sup>+</sup>, Mg<sup>+</sup>, Ca<sup>+</sup>, H<sup>+</sup>, and Na<sup>+</sup> for example, all effect conductivity. Conductivity can be an indicator that these nutrients are present but cannot specify the source.

**Cation Exchange Capacity (CEC) and Base Saturation**

Cation exchange capacity is complicated to understand and simply put refers to the extent to which a soil is able to “hold” nutrients as it relates to the amount of negatively charged particles in the soil. These negatively charged soil particles are called “colloids.” Colloids are either tiny clay or organic matter (humus) particles. The more clay or humus colloids in a soil, the higher its nutrient holding capacity. Negatively charged particles and elements are called “anions”.

Like a magnet, a nutrient must have a positive charge to be held to a negatively charged soil colloid. Calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) all have a positive charge, and are called “cations.” Along with hydrogen (H), these are the primary soil “bases.” However, both calcium (Ca) and magnesium (Mg) have a double positive charge, and are able to push single-plus elements (K, Na, and H) off a negative charge.

**TABLE C.2. CEC AND BASE SATURATION PERCENTAGES**

Sample ID	Soil pH	Cation Exchange Capacity (C.E.C) meq/100g	PERCENT CATION SATURATION (BASE SATURATION %)				
			K%	Mg%	Ca%	H%	Na%
Field A	6.5	13.5	2.9	21.9	64.5	7.5	3.1
Field B	6.1	12.9	4.9	28.0	51.8	14.0	1.2

*Cation exchange capacity* is an index used by soil scientists and soil labs to characterize the capacity of a soil to hold nutrients—the higher the CEC, the higher the soils’ nutrient holding capacity. Increasing soil organic matter, and hence humus

colloids, is a simple way to increase a soil’s CEC. There is no “ideal” or “average” CEC. A CEC of less than 10 is consider on the low end, while a CEC over 25 is considered on the higher end. A sandy soil will have a much lower CEC than a clay soil.

The Table C.2 above is extracted from a standard soil analysis report. As you can see, Field A has a CEC of 13.5 and Field B a CEC of 12.9. Both fields are sandy loams; however, Field A had a much higher percentage of organic matter in the soil (Table C.1). When assessing a soil analysis report, make sure to compare the CEC to the organic matter rating, and look at a soils map to compare differences between fields possibly related to soil texture.

Once you have assessed the nutrient holding capacity of your soils, the next concept to understand is *percent cation saturation*. This is the relative amount of positively charged elements (cations or bases) attached to the soils colloids (anions) expressed as a percent. It includes the three plant nutrients (calcium, potassium, and magnesium), as well as hydrogen and sodium when they are present. Sodium is not an essential plant nutrient, but it can be prevalent in western soils. The percent cation saturation of hydrogen is directly related to the level of calcium in the soil. In the table above, notice that both the soil pH and percent of calcium in Field A are much higher than in Field B.

**CEC %** — This refers to the percent of binding sites occupied by ions.

**ASSESSING NUTRIENT LEVELS FROM A SOIL ANALYSIS REPORT**

Soil test results can vary significantly depending on the time of year the sample was collected. Samples collected just after a crop harvest will be different than if the sample was collected at the beginning of the growing season or soon after a manure application. The best time to sample is just prior

to land application of manure fertilizer. It is recommended that soil sampling be conducted every three to five years, particularly if management practices change significantly.

Results in Table C.3 are reported in parts per million (ppm). To convert parts per million to pounds per acre, multiple the ppm by two. Relative nutrient sufficiency levels are also provided (very low, low, medium, high, very high). For optimum forage or crop productivity, essential nutrient levels should be in the medium to high range (Zimmer, 2000).

TABLE C.3. SOIL ANALYSIS REPORT							
Sample ID	Organic Matter		Phosphorus	Potassium	Magnesium	Calcium	Sulfur
	% Rating	*ENR (lbs/A)	P ppm	K ppm	Mg ppm	Ca ppm	S04-S ppm
Field A	5.5VH	140	48VH	156M	359M	1746M	11M
Field B	4.4H	118	95VH	250M	441VH	1341L	8L

*\* Estimated Nitrogen Release (ENR) in lbs per acre is derived from % organic matter and represents the "potential" amount of organic nitrogen that will be mineralized by soil microbes during the growing season.*

In the example above, Field A is generally well balanced, with the exception of very high phosphorus levels. In Table C.2, the soil pH in this field is close to ideal for most forage species grown in the region at a pH of 6.5. The CEC is also higher than in Field B, possibly due to higher soil organic matter. The Ca-Mg percentages could be improved with the addition of gypsum to raise Ca and lower Mg levels. In Field B, the reverse is true. Calcium and sulfur levels are low, while Mg and K are elevated. The soil pH in this field is also much lower at 6.1. Soil organic matter is also lower than in Field A.





## APPENDIX D

# UNDERSTANDING YOUR MANURE ANALYSIS REPORT

Dairy manure can be used as a fertilizer to supply crops and forages with some or all of the essential macronutrients (nitrogen, phosphorus, and potassium) not otherwise supplied by the soil in sufficient amounts. Animal manures also contain each of the essential micronutrients necessary for plant growth such as calcium, sulfur, and magnesium. Regular additions of manure to cropland and pasture can greatly improve the chemical, biological and physical properties of soil. Solid and composted manure applied to farm fields can significantly increase the amount of organic matter in soils.

## ORGANIC AND INORGANIC NUTRIENTS IN DAIRY MANURE

Nutrients come in two major forms: inorganic and organic. Inorganic forms of nutrients, which are readily available to growing plants, are typically purchased as commercial fertilizers. The majority of nutrients in dairy manure, on the other hand, are in organic form. This basically means that they are chemically bound to organic matter in manure, such as partially digested feed, and are not immediately available as a source of food to growing plants. Organic forms of nutrients include manure solids, crop residues, compost and sludges. In order to become plant-available, organic nutrients must first go through a mineralization process.

Mineralization is the chemical conversion of organic nutrients into inorganic forms that are plant available. It is performed by soil microbes and takes place over time.

The rate of mineralization is affected by soil temperature, moisture content, soil pH, and the availability of food for microbial activity. Dairy pastures and cropland that have consistently received manure applications typically have relatively high levels of soil organic matter and rich reserves of nutrients already present in the soil. In most cases, only 25 percent to 50 percent of organic manure nutrients will be available to plants in the same year they are applied. Organic nutrient sources are thus considered a “slow release” nutrient source.

Nitrogen (N) concentrations are expressed in a number of different forms. Nitrogen is available to growing plants primarily as nitrate ( $\text{NO}_3^-$ ) or ammonium ( $\text{NH}_4^+$ ). Most of the nitrogen used by plants is in the nitrate form. This is because nitrate is mobile and moves with soil water to plant roots, where uptake can occur. During the growing season, when conditions are right, soil organisms change all forms of nitrogen in the soil to nitrate (CPHA, 2002). Most of the nitrogen in soil is a component of organic

matter. Soils with higher levels of organic matter therefore also have higher reserves of plant available nitrogen.

### N-P-K CONCENTRATIONS IN MANURE

Unlike inorganic commercial fertilizers, which can be manufactured and purchased based on recommended N-P-K ratios for specific crops or forages, manures do not have the appropriate nutrient forms and/or ratios to meet specific plant nutrient requirements during peak nutrient uptake. Concentrations of N-P-K in manure can vary significantly based on animal diet, the physical characteristics of the manure (e.g., solid versus liquid), dilution from rain or wash water, the amount of bedding or feed mixed with the manure, and how the manure is collected and stored. It is therefore important to sample and analyze the nutrient content of both solid and liquid manure just prior to land application.

The phosphorous to nitrogen ratio in most dairy manure is roughly 1:2. However, typical forage crops use 1 lb of P for every 4 lbs of N. This means that if manure is applied to meet the nitrogen requirements of a forage crop, twice as much phosphorus will be applied as is needed.

TABLE D.1. NUTRIENT ANALYSES OF SOME ORGANIC MATERIALS (DRY)			
Description	% N	% P2O5	% K2O
Fresh dairy separated solids	2.15	0.85	0.60
Fresh dairy corral scrapings	2.35	1.30	0.70
Aged dairy separated solids	2.05	0.65	0.40
Composted dairy	1.35	1.35	2.85

*Source: Western Fertilizer Handbook (CPHA, 2002).*

### Utilizing Solid Manure Sampling Results

To estimate how many acres would be needed to apply the 5,400 tons of manure from 200 cows at an agronomic rate, you would need to know

- 1) the nutrient content of the manure,
- 2) the amount of nutrients needed by the crop, and
- 3) the amount of nutrients that will be supplied by the soil.

Using the solid manure sampling results in Table D.2, we can begin by figuring out our nutrient supply, focusing on nitrogen and phosphorous.

TABLE D.2. SOLID MANURE SAMPLING RESULTS							
Sample	% Moisture	Pounds of Nutrients/Ton					
		N Nitrogen	P <sub>2</sub> O <sub>5</sub> Phosphate	K <sub>2</sub> O Potash	S Sulfur	Mg Magnesium	Ca Calcium
Farm A	68.3	37.6	8.7	39.5	4.4	11.2	24.6
Farm B	86.5	37.8	27.5	66.5	6.6	21.6	25.2

Based on the manure sampling results for Farm B, there are 37.8 lbs of nitrogen and 27.5 lbs of phosphorus per ton in this sample. If we apply these nutrient concentrations to the entire 5,400 tons of solid manure, we would have a supply of 204,108 lbs of nitrogen and 148,500 lbs of phosphorous.

Determining how many acres would be needed to accept a supply of 204,108 lbs of nitrogen can get complicated because nitrogen is easily lost the environment, primarily through ammonia volatilization and nitrate-Nitrogen leaching to groundwater. There are, however, a number of assumptions you can make when determining an acceptable rate of application.

As a rule-of-thumb, only 25 to 50% of the organic nitrogen applied in a given year is available the first year, the remainder will be released slowly as it decomposes in the soil or lost to the environment. Most of the nitrogen in manure solids

is in organic form. A soils analysis report provides information on the estimated nitrogen release (ENR) in lbs/acre based on the amount of organic matter in the soil. On dairies, it is fair to assume that the ENR in the soils report is the amount of nitrogen available from prior manure applications. Let's assume there is an estimated nitrogen release (ENR) from the soil on this dairy of 100 lbs/acre.

**Utilizing Liquid Manure Sampling Results**

**TABLE D.3. LIQUID MANURE SAMPLING RESULTS**

Samples	N (ppm)	P2O5 (ppm)	K2O (ppm)
Farm A	1,600	230	2,040
Farm B	4,800	1,610	5,280

Let's assume that the same two dairy farmers each have a lagoon capacity of 5 acre-feet, and that the lagoons are full. In which case, the farmers would need to spread 60 acre-inches of lagoon water. To determine how much land Dairy Farmer A would need in order to apply nitrogen at an agronomic rate (300 lbs/acre) we start by multiplying 1,600 ppm by 0.2268 to get 362.88 lbs N/acre-inch. Farmer A has a total nitrogen supply of 21,772.8 lbs (multiplying ppm by 0.008 would give you lbs/1,000 gallons).

Unlike the nitrogen in solid manure, most of the nitrogen in the lagoon water will be in a plant available form. Therefore, to meet a nitrogen requirement of 300 lbs/acre the farmer would need approximately 73 acres of land, without crediting the 100 lbs/acre of nitrogen in the soil reserves. If using a fertigation system, it is recommended that applications be split into thirds during the growing season to maximize forage yields and minimize the movement of nitrate to groundwater (Meyer and Andersen, undated).

One of the primary benefits of good solids separation is that it allows greater control over the amount and ratios of nutrient

applications. As is evident in the table above, the nitrogen to phosphorous ratio in lagoon water is much more in line with the actual nutrient requirements of most crops, which is basically 4:1 for N and P. Using Farm A sample results, the operator has a total of 3,130 lbs of phosphate in the lagoon water. To apply this amount of phosphorous at an agronomic rate of 90 lbs/acre would require only 34 acres of land. Make sure to consult your soils report when deciding where to apply solid manures, and where it might be best to apply liquids. Avoid applying solid manure to fields with very high soil phosphorous levels.

**TABLE D.4. MANURE NUTRIENT CHARACTERISTICS**

Nutrient	Percent excreted in manure	
	Feces	Urine
Nitrogen (N)	48%	52%
Phosphorus (P)	97%	3%
Potassium (K)	30%	70%
Calcium (Ca)	99%	1%

**THE NITROGEN FRACTION OF MANURE**

Plants required more nitrogen than any other plant nutrient, and sufficient amounts of nitrogen are essential for maintaining good crop and forage productivity. Of all the nutrients in manure, nitrogen is the most vulnerable to environmental losses. Manure is often over-applied to compensate for potential environmental losses of nitrogen. Therefore, nitrogen concentrations in manure and appropriate application rates need to be carefully determined to avoid adverse air and water quality impacts as well as soil acidification (Kinsey, 2006). Steps taken to conserve the fertilizer value of manure nitrogen will also help minimize adverse impacts to the environment.

In urine, the organic fraction of nitrogen is largely in the urea form (60-90%). Urea is a highly unstable compound

that is rapidly converted into ammonia. How and when manure is land applied can also have a significant impact on losses of nitrogen. For instance, surface application of slurries can result in losses of 10 percent to 25 percent of the available nitrogen due to ammonia volatilization. Applying liquid manure during periods of peak plant growth is one way to optimize its value and minimize nitrogen losses.

Most of the nitrogen in manure solids (feces) is in an organic form, and will not be available to growing plants until it is converted by soil microbes into ammonium nitrogen.

A rule of thumb is that 25-50% of the organic nitrogen applied in a given year is available the first year, 25% in the second, 5-10% in the third and 5% in the fourth. A soil analysis report will provide information on estimated nitrogen release (ENR) in lbs/acre based on the amount of soil organic matter in the soil sample.

### **THE PHOSPHORUS FRACTION OF MANURE**

Manure solids and slurries contain almost all of the phosphorus excreted by livestock. This is because phosphorus chemically binds to organic matter. Phosphorus will also chemically bind to soil particles, and once land applied, will remain (for the most part) in the soil until utilized by plants.

While phosphorus is less mobile than nitrogen, research has shown that high levels of soil phosphorus directly correlate with elevated levels of phosphorus in surface water runoff (Pant et al). Farm fields that have consistently received manure applications typically have sufficient soil reserves of phosphorus to meet plant nutrient requirements.

### **THE POTASSIUM FRACTION OF MANURE**

Seventy percent or more of the potassium excreted by livestock is in a soluble form. Potassium is not known to cause water

quality impacts, although excessive levels of potassium in crops and forages can lead to livestock health problems such as milk fever. Soils naturally contain many thousands of pounds of potassium per acre, though only a small percentage is available to plants (1 to 10 percent). Large amounts of potassium are removed from the soil when vegetation is removed, as in a silage or hay crop (CPHA, 2002). The only way to accurately determine the potassium content of your manure is to have it sampled and lab analyzed just prior to land application.

### **UTILIZING LIQUID MANURE NUTRIENT ANALYSES:**

To calculate the amount of liquid manure nutrients you are applying per acre based on sampling results use the following steps:

Determine how many pounds of a nutrient are applied per acre-inch of water.

\_\_\_\_\_ ppm x 0.2268 conversion factor =  
\_\_\_\_\_ lbs/acre-inch of water applied

Depth in -inches of liquid manure applied to the field = \_\_\_\_\_ -inches /acre

How many pounds of the nutrient are applied per acre?

Answer to question #1 x Answer to question #2 = \_\_\_\_\_ lbs nutrient/acre

*Example:*

How many pounds of nitrogen (N) are applied per acre if 1 acre-inch of liquid manure is applied per acre, and the concentration of nitrogen is 2,882 ppm?  
(1 acre-inch = 27,152 gallons)

2,882 ppm of N x 0.2268 = 654 lbs N/acre-inch of water

2.80 -inches of water applied per acre

654 lbs of N/acre-inch x 2.0 inches = 1,304 lbs of N/acre

APPENDIX E

# USEFUL CONVERSIONS

**CONVERSIONS FOR LIQUID OR SLURRY MANURES:**

ppm x 0.2268 = pounds per acre-inch  
 ppm x 0.008 = pounds per 1,000 gallons

**CONVERSIONS FOR SOLID MANURES AND COMPOSTS:**

ppm x 0.002 = pounds per ton  
 percent x 20 = pounds per ton  
 ppm / 1,000,000 x lbs/yd (bulk density) = lbs/yd

**CONVERSIONS FOR BULK DENSITY**

Most manure is spread by trucks and the applications are measured in cubic yards rather than tons. The weight of a cubic yard of manure is its bulk density. A lab can determine bulk density or an operator can determine bulk density by using a 5 gallon bucket and a scale. To determine the bulk density of manure, fill the 5 gallon bucket from a few separate locations in manure pile and weigh each bucket full.

Average the weights of sampled buckets of manure x 40 = lbs per cubic yard (lbs/yr<sup>3</sup>)

*Example:*

**TABLE E.1. LAB RESULTS REPORTED ON AN AS-RECEIVED BASIS**

units	N	P	K
lbs/ton	12	2	4

The average weight of 6, 5-gallon bucket samples equaled 34lbs.

$$34\text{lbs} \times 40 = 1360\text{lbs/yr}^3$$

$$1360 \text{ lbs/ yr}^3 / 2000 \text{ lbs/ton} = 0.68 \text{ tons/yr}^3$$

Multiply values in table x by 0.68 to get lbs applied per cubic yard of manure.

**TABLE E.4. LAB RESULTS CONVERTED FROM LBS/TON TO LBS/YD<sup>3</sup>**

units	N	P	K
lbs/yr <sup>3</sup>	8.2	1.4	2.7

**ELEMENTAL AND OXIDE FORMS OF NUTRIENTS**

Phosphorus (P) and potassium (K) concentrations are expressed either in their elemental form, or in the oxide form as P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O. Most agricultural labs that do manure testing report the results in the oxide form since this is how fertilizer recommendations are made. If the results are reported in the elemental form, they will have to be converted to the oxide form for use in nutrient management planning.

Standard Conversion Factors:     P x 2.3 = P<sub>2</sub>O<sub>5</sub>  
    K x 1.2 = K<sub>2</sub>O



APPENDIX F

# MEASURING RESIDUAL DRY MATTER (RDM)

Residual dry matter (RDM) is a standard used for assessment to determine the level of grazing on annual grasslands. Residual dry matter is the amount of old (dead) plant material left at the end of a growing season (Bush, 2008). Generally RDM is used as an indicator for land managers to determine if they are grazing at desired levels. Low levels of RDM can indicate over grazing which has the potential to lead to issues such as nutrient losses, and soil erosion (James W. Bartolome, 2002). Below are two tables that provide guidelines for desired amounts of RDM for grasslands on varying slopes, for both annual grassland/hardwood range (annual understory with variable oak or shrub canopy, average rainfall between 12 and 40 inches) and coastal prairies (perennial grasses common, variable woody overstory, rainfall variable). Residual dry matter guidelines for dairies in coastal Sonoma County would probably fall somewhere between these two examples.

*Tables F.1 and F.2 adapted from (James W. Batolome, 2002)*

To get help learning how to measure RDM contact your local NRCS office, a certified range manager or refer to the Grazing Handbook (Bush, 2008) located on the Sotoyome Resource Conservation District website, <http://sotoyomercd.org/GrazingHandbook.pdf>.

**TABLE F.1 MINIMUM RESIDUAL DRY MATTER (RDM) GUIDELINES FOR ANNUAL GRASSLAND/ HARDWOOD RANGE.**

Percent Woody Cover	0-10% Slope	10-20% Slope	20-40% Slope	>40% Slope
<b>lbs RDM per acre</b>				
0-25	500	600	700	800
25-50	400	500	600	700
50-75	200	300	400	500
75-100	100	200	250	300

**TABLE F.2 MINIMUM RESIDUAL DRY MATTER (RDM) GUIDELINES FOR COASTAL PRAIRIE.**

Percent Woody Cover	0-10% Slope	10-20% Slope	20-40% Slope	>40% Slope
<b>lbs RDM per acre</b>				
0-25	1,200	1,500	1,800	2,100
25-50	800	1,000	1,200	1,400
50-75	400	500	600	700
75-100	200	250	300	350





APPENDIX G

# DETERMINING MANURE PRODUCTION

## Lagoon Capacity

### DAILY MANURE PRODUCTION

Average values for manure generation by age and weight class are provided in Table G.1.

### DAILY MANURE PRODUCTION RATES AND CHARACTERISTICS

The first step in developing a “manure utilization plan” is to estimate the amount of manure generated on the dairy as well as its nutrient content. With these estimates in mind, it is then possible to figure out the approximate amount of land that will be needed to apply the manure at agronomic rates. Many producers may already have accurate estimates of yearly manure production rates based on annual manure hauling records. Knowing the amount and characteristics of the manure that is hauled annually will make it much easier to preplan application rates based on manure sampling results. Average book values for manure generation by age and weight class are provided in Table 3a.

TABLE G.1. DAILY MANURE PRODUCTION				
Animal	Size (lbs)	Total Manure		
		(lbs/day)	(ft <sup>3</sup> /day)	(gal/day)
Lactating Cow	1,000	106	1.7	12.7
	1,400	148	2.4	17.7
Dry Cow	1,000	82	1.30	9.7
	1,400	115	1.82	13.6
Heifer	750	65	1.0	7.8
Veal Calf	250	9	0.14	1.1
Calf	150	13	0.20	1.5

*Source: MWPS Table 6*

Using book values, a 1,400-pound dairy cow produces approximately 148 pounds of feces and 18 gallons of urine per day. In one year, she will produce roughly 27 tons of solid manure and 6,570 gallons of urine. A 200 cow milking herd would produce on the order of 5,400 tons of solid manure a year. A manure truck with a 20 cubic yard capacity can haul approximately 15 tons of fresh manure (1 cubic yard equals .75 tons). Hypothetically, it would take 360 truckloads to haul the 5,400 tons of solid manure. [Address issue of bedding and spoiled feed]

The weight of the manure and its nutrient content per ton is determined by moisture content. Fresh manure has a moisture content of roughly 85%. This is important to know because nutrient concentrations provided in manure sampling reports are expressed on a 100% dry matter basis. If you reduce the moisture content of the manure by half, you will eliminate half its weight. In this example, good solids separation or composting could save an operator the fuel and labor costs of hauling an additional 180 truckloads of manure. Reducing the weight of the manure does not reduce its nutrient content in equal measure. Most of the nutrient value is retained in the manure, with the exception of nitrogen. A percentage of the nitrogen will be lost to the atmosphere through ammonia volatilization. The same nitrogen loss will occur, however, if the wetter manure is applied to farm fields without incorporation into the soil.

**TABLE G.2. DAILY AND YEARLY EXCRETION OF N, P, AND K BY A 1,400-POUND DAIRY COW**

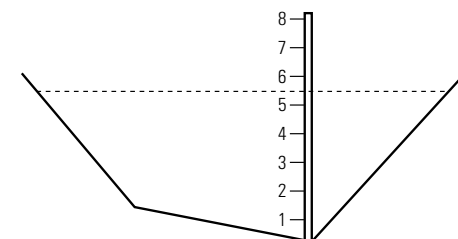
	0-30 DIM	31-100 DIM	101-305 DIM	60-day Dry Period	Yearly Total
Milk, lbs/cow	100	70	50	Dry	21,750 lbs
DMI, lbs/cow	55.8	46.3	39.2	25.2	14,462 lbs
<b>Pounds N excreted/day</b>					<b>Lbs/cow/yr</b>
Total N (low protein degradability)	0.89	0.73	0.60	0.36	223
Total N (high protein degradability)	1.03	0.85	0.70	0.44	260
<b>Pounds P excreted/day</b>					<b>Lbs/cow/yr</b>
0.40% P in diet	0.123	0.115	0.107	0.101	40
0.45% P in diet	0.151	0.138	0.136	0.103	46
0.60% P in diet	0.235	0.208	0.185	0.151	69
<b>Pounds K excreted/day</b>					<b>Lbs/cow/yr</b>
0.80% K in diet	0.296	0.265	0.239	0.201	88
1.2% K in diet	0.519	0.450	0.396	0.302	146

### MEASURING POND (LAGOON) CAPACITY

Knowing your pond capacity is essential for tracking manure application. Pond systems can vary in shape and size. The image below will help determine your pond capacity. For more help you can hire an engineer or contact your NRCS area district office.

**TABLE G.3. POND VOLUME**

Depth	Pond Volume
8 ft	1 x 10 <sup>6</sup> gallons
7 ft	800,000 gallons
6 ft	650,000 gallons
5 ft	500,000 gallons
4 ft	375,000 gallons
3 ft	275,000 gallons
2 ft	175,000 gallons
1 ft	75,000 gallons



To calculate volume:

Length \_\_\_\_\_ x Width \_\_\_\_\_ x Depth \_\_\_\_\_ = Volume \_\_\_\_\_