Constructed Wetlands in Arizona for Agricultural Wastewater Treatment

Technical Evaluation and Guidance

Arizona Department of Environmental Quality
in cooperation with
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Acronyms

ADA	Arizona Department of Agriculture
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AGFD	Arizona Game and Fish Department
APP	Aquifer Protection Permit
AWQS	Aquifer Water Quality Standards
AU	Animal Unit
AWMS	Agricultural Waste Management System
BMP	Best Management Practice
BOD_5	Total 5 day biochemical oxygen demand
CAFO	Concentrated Animal Feeding Operation
CWA	Clean Water Act
DPC	Dairy Products Control office
FWS	Free Water Surface
NH_3	Ammonia
NH_4	Ammonium
NO_3	Nitrate
NRCS	Natural Resources Conservation Service
PMO	Pasteurized Milk Ordinance
SA	Surface Area
SCS	Soil Conservation Service
SF	Surface Flow
TN	Total Nitrogen
TS	Total Solids
TSS	Total Suspended Solids
TVA	Tennessee Valley Authority
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency

Executive Summary

In 1989, the Arizona legislature mandated nitrogen pollution minimization goals for certain agricultural activities, including concentrated animal feeding operations (CAFOs). These goals, termed Best Management Practices, are the basis by which regulated agriculture is required to prevent and minimize nitrogen pollution.

This document is intended to provide owners,operators, and designers of CAFOs and associated waste management systems with an alternative method for meeting state requirements for minimization of nitrogen pollution. Current information for application of constructed wetlands in an agricultural setting has been compiled in this report. However, at the time of drafting of this document, there are no known constructed wetlands in Arizona which treat agricultural wastewater generated by concentrated animal feeding operations. It is therefore anticipated that components outlined in this guidance document will require fine tuning after initial wetland structures have been constructed in Arizona.

Guidance presented in this document builds on the existing Technical Requirements developed by the USDA Natural Resources Conservation Service for constructed wetlands for agricultural wastewater treatment. These requirements are based primarily on studies of municipal waste treatment systems. Components added to the national NRCS Technical Requirements for the development of this document address issues specific to Arizona. These include arid climate, plant selection, water management and regulatory issues. Due to variable conditions such as climate and water availability within the state, many potential constructed wetlands will have site specific requirements.

Introduction

In Arizona, there are more than 200 commercial concentrated animal feeding operations. They include approximately:

30 swine operations in Northeastern and Southeastern Arizona,

125 dairy operations, most in Maricopa and Pinal Counties,

14 beef cattle feeding operations,

6 poultry/ostrich operations, and

35 aquaculture operations.

These operations are under increasing regulatory pressure to manage animal waste produced on site in an environmentally acceptable manner. Since 1989, the state has mandated nitrogen discharge minimization of CAFOs. Nitrogen minimization mandates are in the form of Best Management Practices (discussed in Chapter 9) which are vested in rule and administered through the Arizona Department of Environmental Quality (ADEQ). Additionally, water conservation requirements are imposed on water users in certain parts of the state known as Active Management Areas (AMA). Water conservation regulations are administered through the Arizona Department of Water Resources (ADWR) (discussed in Chapter 9). CAFOs residing in AMAs are required to meet maximum water use goals per animal.

Managing waste and nitrogen contaminated water in an environmentally acceptable way is achieved through an Agricultural Waste Management System (AWMS). Each operation has site specific requirements and opportunities for waste management. It is important to understand that a constructed wetland is only one component of an overall AWMS. The AWMS should be designed to provide for production, collection, storage, treatment, transfer and utilization or disposal of wastes (USDA AWMFH 1992). **These guidelines examine the use of constructed wetlands as a treatment alternative within the total system.**

Recognizing there are infinite options in structures, use of plant materials, and hydraulic regimes ---- this document attempts to focus on a design type that has the most documented information and is the simplest to present conceptually. There is no intention to limit creativity in application of a constructed wetland, rather to provide guidance within a specific design framework.

Systems such as floating aquatic plants and submerged flow beds have potential advantages in the southwest. Some management peculiarities and potential problems are beyond the scope of this assessment and therefore are not addressed in this document. Further research of these systems is needed before technical criteria can be set forth in this report.

To address the treatment of agricultural wastewater with constructed wetland technology in detail, the types of agricultural wastewater that occur in Arizona must be defined. Generally, there are two sources of agricultural wastewater. The first is wastewater resulting from the operation of CAFOs. This includes wastewater which results when water is used for processing animal products, cleaning animals and equipment, cooling animals, and storm water runoff. The second source of agricultural wastewater is irrigation "tailwater" or the water applied during an irrigation that runs off the irrigated field. The potential for treatment of irrigation wastewater is complicated by the variety of agrichemicals contained in the runoff, seasonal variation in water supply, and existing regulations addressing both water quantity and quality. For this reason, treatment systems for irrigation wastewater will not be addressed in this document. Only agricultural wastewater associated with CAFOs will be addressed in this document.

HOW TO USE THIS BOOK

Because of the broad audience for constructed wetlands information, this document is organized into two sections. The first section targets those individuals interested in the design and construction of a constructed wetland (Chapters 2,3, and 4), while the second section addresses water management, vegetation, operation and maintenance, monitoring and regulatory requirements (Chapters 5 through 9). This second section is intended for the owner/operator of a CAFO. System operators should be familiar with both sections, but the authors recognize that operators may prefer to contract for design and construction of the wetland. Thus, it is hoped that information is organized in a useable arrangement.

Most chapters end with a summary outline entitled, "Points to Apply." This provides a brief overview of important points in the chapter. It is intended to serve as a quick reference/checklist for the designer or operator. Chapter 9 (Regulations) and Appendix A (Sources of Technical and Financial Assistance) provide users with additional contacts.

CHAPTER 1
CONSTRUCTED WETLANDS

What is a Constructed Wetland

This document describes the technical requirements for the use of constructed wetlands in an AWMS with the goal of improving water quality. Although other systems exist, such as subsurface flow and floating aquatic plants, this design guidance applies to free water surface (FWS) systems. FWS systems consist of adequate seepage control, a suitable plant medium for vegetation, rooted emergent vegetation, wastewater flowing at a slow velocity through the system, and the structural components needed to contain and control the flow. Important components of FWS systems are emergent vegetation and shallow water flow. Subsurface Flow systems typically contain rock media, and emergent vegetation with wastewater passing through the media, without surface flow. Floating Aquatic systems are shallow ponds with floating or submerged aquatic plants, such as hyacinth or duckweed.

Constructed wetlands treat wastewater in several ways, including settling, biochemical conversion, volatilization, evapotranspiration, and nutrient uptake. Within the water column, plant stems serve as substrate for bacteria and other microorganisms important in the treatment process. This is perhaps the most important treatment mechanism in a constructed wetland. When wetland plants translocate oxygen from the upper plant tissue to the roots, it is thought that oxygen diffuses through the roothairs to form a thin oxygen-rich zone where aerobic decomposition can occur. Additional nitrogen reductions occur as a result of plant uptake.

Why and When Would a Constructed Wetland be Considered

Potential advantages exist for using constructed wetlands rather than existing technologies. These include:

1. Water Conservation and Reuse. Water which has completed treatment in a constructed wetland could be reused for flush water to clean facilities, on farm roads for dust control, or for cooling animals and equipment. This is particularly important in Active Management Areas where the quantity of water used is regulated by the Arizona Department of Water Resources.

2. Costs associated with waste system installation. In eastern states, constructed wetlands have been demonstrated to be the lowest cost waste management alternative.

3. Best Management Practices for Regulated Agricultural Activities were certified into rule by the Arizona Attorney General in January 1991 (R18-9-201 et seq.). These rules include management practices for operation and closure of CAFOs as well the application of nitrogen fertilizers to agronomic crops. These practices are intended to protect ground and surface water quality. Management of CAFO wastewater may require additional treatment, such as in a constructed wetland, to minimize surface and groundwater contamination by nitrogen.

The following issues may limit application of constructed wetland systems in Arizona:

1. Supplemental fresh water required to maintain constructed wetlands subjected to wastewater discharges may be necessary. Fresh water may be required for dilution of the animal wastes or simply to maintain vegetation in the constructed wetland during periods of high evaporation. Addition of supplemental water may be cost prohibitive in regulated areas, and water allotments to water users may not be sufficient.

2. Regulatory issues such as Aquifer Protection Permit, Reuse permitting, and requirements for synthetic liners may make constructed wetlands a cost prohibitive alternative.

3. Retrofitting existing facilities for reuse of water may also be cost prohibitive for some operations.

4. It may not always be possible to integrate the design considerations for a constructed wetland which is sized to both maintain vegetation and meet treatment requirements. For example, it may be helpful to downsize a constructed wetland in arid regions and increase pretreatment storage of wastewater to assure water supply throughout high evaporation periods. Such a downsized system may not treat wastewater consistently year round. In states where constructed wetlands have demonstrated success, precipitation exceeds evaporation. This supplies sufficient moisture to maintain constructed wetland vegetation during periods when wastewater is not being applied.

In evaluating the appropriateness of a constructed wetland for a specific facility, the following questions should be considered:

1. What are the agricultural wastewater treatment needs for my operation?

This can be determined through a facility assessment. Inventory worksheets in Appendix B will help quantify production. Existing treatment methods should have sufficient capacity to store and treat animal wastewater produced. Projected growth should be included in capacity determination. If a facility is unable to manage present or projected volume of wastewater, alternatives will have to be considered and may include a constructed wetland.

2. Does the existing or planned AWMS meet BMPs for concentrated animal feeding operations?

The following practices apply:

a. Harvest, stockpile and dispose of manure from concentrated animal feeding operations to minimize discharge of nitrogen by leaching and runoff.

b. Control and dispose of nitrogen contaminated water resulting from activities associated with a concentrated animal feeding operation, up to a 25 year, 24 hour storm event equivalent to minimize the discharge of nitrogen pollutants.

If these practices are not being met by an existing system, alternatives such as a constructed wetland could be considered and implemented.

3. If treated wastewater will be used for irrigation or reuse in the facility, what is the water quality after present treatment for these uses? What is water quality required for these uses?

Wastewater should be tested for parameters that affect intended uses (mainly nitrogen, oxygen and coliform bacteria) before implementing a constructed wetland. Treatment needs and appropriate alternatives, such as a constructed wetland, can then be identified. Refer to Chapter 8 (Monitoring) for more detailed information.

If answers to the above questions identify the need for changes in an existing agricultural waste management system, owner/operators may want to consider a constructed wetland. Chapter 9 (Design) includes an introduction of design considerations to evaluate the initial feasibility of a constructed wetland, as well as more detailed information for the designer.

Summary of Technical Requirements

The following is a summary of the requirements for planning design, construction, monitoring, and operation and maintenance of constructed wetlands built for CAFOs. These requirements are explained in greater detail in the appropriate sections of this document.

- Constructed wetlands will be a component of a planned AWMS.
- Wastewater to be treated by constructed wetlands will originate from livestock or aquaculture facilities.
- Wastewater to be treated by a constructed wetland should only include runoff from feedlots or barnyards if it is pretreated by passing through a storage/treatment component. The constructed wetland should be protected from direct run on.
- Wastewater will be pretreated to reduce the concentration of nutrients and solids before it is introduced into constructed wetlands.
- Wastewater will be of sufficient volume and duration to keep the constructed wetland moist of sufficient duration to support wetland vegetation.
- Constructed wetlands will be planned, designed, constructed, operated and maintained in accordance with all Federal, State, and local laws and regulations.
- Constructed wetlands will be sited outside the limits of jurisdictional wetlands of any classification.
- Operation and maintenance plans developed for constructed wetlands will include at least the minimum level of monitoring. This will include monitoring for nitrogen, biochemical oxygen demand and coliform bacteria (refer to chapter 8 on Monitoring).
- Constructed wetlands will be designed as a surface flow or free water surface type (subsurface flow type systems will not be permitted until research demonstrates their long term effectiveness).
- When necessary, constructed wetlands will discharge to storage facilities to allow for land application in an environmentally sound manner or recycle wastewater through the agricultural waste management system.

- The constructed wetland should be designed to discourage use by wildlife which may be negatively impacted. Where feasible, large animals (deer, elk, javelina, etc.) should be fenced out.
- To the extent possible, constructed wetlands are to be sited and designed to fit the topography, vegetation and other land use patterns, and are to be an integral part of the designed ecosystem.

Alternative agricultural waste management systems should be carefully considered in determining if a constructed wetland is an appropriate component of a system which will be resource efficient, resource conserving, economically feasible, socially supportive, and environmentally sound. The USDA NRCS (formerly SCS) Agricultural Waste Management Field Handbook should be referenced in making these considerations as it gives details needed in planning agricultural waste management systems. It may also be helpful in the design of constructed wetlands.

CHAPTER 2
DESIGN

I. Overview of Design

Many components are involved in the design of a constructed wetland for agricultural purposes. The following overview of design considerations is presented for those operators, or other individuals, who may want a summary of these factors. These components are discussed in greater detail later in this chapter.

AGRICULTURAL WASTE MANAGEMENT SYSTEM

A constructed wetland may be applied as part of an overall agricultural waste management system. The system should perform six basic functions: production, collection, storage, treatment, transfer and utilization (USDA SCS AWMFH 1992). A constructed wetland as defined in this guidance, addresses treatment and in some cases storage of agricultural waste and wastewater.

PRETREATMENT

Due to the concentration of most animal waste, pretreatment will be necessary prior to entering the wetland. The quality of constructed wetland influent will be determined by the characteristics of the wastewater and degree of pretreatment. Constructed wetlands will be used as a secondary treatment following a primary treatment system (Eddleman 1993). Pretreatment methods include anaerobic or aerobic lagoons, solid separators, and settling basins. The method chosen for a facility may be determined based on existing structures and/or primary treatment requirements (based on quality of wastewater).

WATER BUDGET

In arid climates, water budgets will be important for vegetation maintenance and proper treatment levels. Due to significant seasonal variation in water use and evapotranspiration, it is suggested to calculate monthly water budgets so storage requirements can be incorporated into the design. Recycling treated wastewater through the system may be desired.

GROUND WATER PROTECTION

Soils in the construction area will be identified to determine the water holding capacity. Soil survey information will give general information about permeability and compaction characteristics of the specific soils (Eddleman 1993). Prior to construction, onsite investigation by a soil scientist is recommended. Constructed wetlands designed with this document will provide adequate containment of wastewater within the system to prevent contamination of groundwater.

SIZE REQUIREMENTS

The constructed wetland will be sized by determining the total five day biochemical oxygen demand, BOD_5, entering the constructed wetland daily. The minimum size will be determined by constructing 750 square feet of surface for each pound of BOD_5 entering the constructed wetland daily (Eddleman 1993). Additionally, for nitrogen minimization the total nitrogen (TN) loading rate should not exceed 9 lb/surface acre of constructed wetland daily (Hammer 1993). Future plans for expansion should be provided for in design of an agricultural waste management system.

CONFIGURATION

The constructed wetland should be shaped with a minimum overall length to width ratio of 4:1. This overall layout should then be subdivided into parallel cells, each having a length to width ratio of about 10:1 (see figure 2-2 on page 27). Two or more cells will facilitate management should any one cell require maintenance.

REUSE

A small sump or pit can be constructed to catch any outflow of water which can be recycled for flush systems or through the waste management system. Please refer to chapters 5 and 9 (Water Management and Regulations) for other considerations in reuse of treated wastewater.

REGULATORY ISSUES

Prior to design of a constructed wetland, operators and designers should review Chapter 9 of this book regarding regulations that could impact an agricultural waste management system. Some permitting requirements by state and federal agencies may affect siting and design of an AWMS.

II. Agricultural Waste Management System

A. Agricultural Waste Management Plan

Constructed wetlands are only one of several options to be considered as a treatment component within an overall waste management system. An acceptable animal waste management system contains all necessary components to manage liquid and solid waste, including runoff from concentrated waste areas, in a manner that does not degrade air, soil, or water resources. The purpose of the system is to protect those resources, as well as public health and safety. Such systems are planned to preclude discharge of pollutants to surface or groundwater and to recycle waste through soil and plants to the fullest extent practicable (USDA SCS 1979). A waste management system plan which maximizes the value of animal waste as a land resource should contain:

- General layout maps of facility
- Computations showing:
    1. quantity of waste being handled
    2. contaminated runoff to be handled (25 year, 24 hour storm)
    3. design of the system
    4. utilization method and area required
- Detailed plans and specifications for all designed components.
- Operator's management plan.

(USDA SCS AWMFH 1992)

Sources of technical information on other system components are listed in the appendices and bibliography, and can be located with the assistance of your local NRCS or Cooperative Extension office.

B. Pretreatment Requirements

Due to the concentrated nature of animal waste, pretreatment of influent discharged into a constructed wetland is necessary (Hammer 1993). The quality of the constructed wetland influent will be determined by the characteristics of the wastewater and the degree of pretreatment. Influent quality must be controlled to manage the characteristics of the wastewater treated in the constructed wetland. Pretreatment will remove most settleable solids and materials that are not readily biodegradable. It will also reduce nutrient and organic loads which will help survivability of the constructed wetland vegetation. Dilution of the wastewater may be required to reduce the concentration of nitrogen and other constituents which could damage plants if applied at high concentrations. Wherever possible, use of lagoons for storage and treatment will be encouraged to reduce dilution requirements. According to Hammer (1993), primary treatment should achieve a 50% reduction of the BOD_5 and Total Suspended Solids (TSS) loading in the waste stream. (BOD_5 is an indirect measure of the concentration of biodegradable substances present in the wastewater. Five day BOD refers to the amount of dissolved oxygen required during the initial five days of the anaerobic degradation process.) Estimated percent reductions in BOD_5 for single-cell anaerobic lagoons is 75% in warm climates and 60% in cool climates. Different values of percent reduction will have to be established for other lagoon configurations and storage periods as experience yields local values. Target concentrations resulting from wastewater pretreatment for wastewater entering constructed wetlands should not exceed 1,500 mg/l total solids (TS), and 100 mg/l ammonia. Methods for pretreatment include lagoons, settling basins, dilution, and mechanical separation used alone or in combination with other practices. These methods are illustrated and discussed further in USDA (SCS) NRCS Agricultural Waste Management Field Handbook available through local NRCS offices.

A recommended system configuration to treat organic and nutrient loading includes a sequence of four components: a lagoon, a marsh, a pond, and a meadow (Hammer 1993). However, this can result in a land intense system. The pond and meadow components can be deleted while still reducing organic load and bacterial load. The loading rate of nitrogen must be reduced by dilution, or structural modifications made of some components, to achieve acceptable nitrogen treatment. Another suitable pretreatment practice could include solid separation, anaerobic and aerobic lagoon in sequence, followed by a constructed wetland. Incorporating lagoon(s) provides storage capacity for seasonal variations in application to the wetland, reduces the treatment area needed in the wetlands, and accomplishes pollutant reduction more efficiently than a stand-alone wetlands system (Hammer 1993).

Under these design criteria, the treatment area required for a constructed wetland is based on organic loading (the characteristics of waste supplied). The total agricultural waste management system, including lagoons and constructed wetland, should be designed based on hydraulic loading to ensure adequate storage and availability of seasonal water supplementation. The treatment area for the constructed wetland is determined by: 1) the quantity of incoming organic wastes to be treated per day; and 2) the capacity for a given area of wetlands to treat a fixed quantity of wastewater per day (Hammer 1993). The quantity of wastes to be treated can be determined by completing the USDA NRCS worksheets in Appendix B. Organic load should then be determined by testing the wastewater for an existing facility. For a new facility, typical parameters from literature or similar systems should be used. The USDA NRCS Agricultural Waste Management Field Handbook is a source of information for both quantities and quality of livestock waste. The concentration of animal wastes is much greater than domestic sewage, even after some level of treatment. For example, the BOD_5 value for raw domestic sewage ranges from 200 to 300 mg/l (USDA SCS AWMFH 1992). As seen in Table 2-1, animal wastewater concentrations can be much greater. Concentrations will vary considerably from these values, depending on lagoon size, seasonal temperatures, and water use of the operation. The values in Table 2-1 are from pretreatment in a lagoon, and do not reflect any level of treatment in a constructed wetland.

Table 2-1 **A sampling of influent BOD_5 concentrations and range of animal wastewater concentration for various types of anaerobic lagoons (USDA SCS AWMFH 1992)**

Sources	Lagoon influent	Lagoon wastewater
	--------------------mg/l--------------------	
Dairy	6,000	200-1,200
Beef	6,700	200-2,500
Swine	12,800	300-3,600
Poultry	9,800	600-3,800

C. Organic and Nitrogen Loading

The total organic load generated per day can be used to evaluate the treatment capacity available in an existing anaerobic or aerobic lagoon or to design a lagoon to provide primary treatment (Hammer 1993). Once the level of preliminary treatment is established, the appropriate size for a constructed wetland can be calculated. The constructed wetland treatment area often used for municipal systems to reduce organic loads to secondary discharge levels of <30 mg/l of BOD_5 is the equivalent of 90 lbs BOD_5/ac/day. For NH_3 discharge levels below 10 mg/l, the total nitrogen (TN) loading rate must not exceed 9 lbs/ac/day (Hammer 1993). In Arizona, nitrogen is the regulatory impetus for these systems, thus, it is important to assure structural design meets nitrogen loading requirements. These design guidelines are based on BOD_5 measurements and typically provide adequate nitrogen reduction in combination with the pretreatment methods discussed.

The following treatment objectives were established by the NRCS for technical guidance on constructed wetland design. They are not intended to be used to the exclusion of additional treatment goals of the operator. State and local regulatory agencies should review treatment objectives of any planned constructed wetland to assure all regulatory requirements for treatment are identified. Minimum NRCS treatment objectives are:

- BOD_5 <30 mg/l
- TSS <30 mg/l
- $NH_3+NH_4+NO_3$ <10 mg/l

Animal wastewater from the constructed wetland that is stored and then land applied is not generally held to the above treatment objectives, but must meet nitrogen minimization goals set forth by the state. This can be achieved by developing and implementing a nitrogen management plan for the agronomic crops utilizing the wastewater. The local NRCS or Cooperative Extension Service can assist operators in developing a nutrient (nitrogen) management plan.

D. Water Budget

Water budgets are important in arid climates to maintain both wetland vegetation and proper treatment levels. Generally, water budgets are determined over a one year period. In southern Arizona, annual evaporation exceeds precipitation. Due to significant seasonal variabilities in water use and evapotranspiration, it is suggested that a monthly water budget be calculated so storage requirements can be incorporated into the design.

The US Environmental Protection Agency (USEPA) cites the following equation for determining water balance in a constructed wetland:

Qi + P = Storage + Et + Qo

Qi = influent wastewater flow, volume/time

Qo = wastewater outflow, volume/time

P = precipitation, volume/time

ET = evapotranspiration, volume/time

Storage = storage capacity of AWMS (including constructed wetland), volume/time

An inventory of monthly wastewater generation and storage capacity/requirements is necessary to determine Qi. Worksheets found in Appendix B can be used for inventory calculations.

Groundwater inflow and infiltration are not considered in the equation. Sites with high water tables or highly permeable soils should be designed as impermeable, otherwise alternative systems should be considered (USEPA 1988). The potential for vegetation damage from salinity concentration will be increased when infiltration and groundwater inflow are eliminated. This should be compensated for by ensuring surface discharge from the wetland cell whenever possible.

Historical climate records can be used for precipitation and evaporation estimates. Average annual precipitation figures can be found in region descriptions in Chapter 6 of this document. The University of Arizona Cooperative Extension has weather stations throughout the state which record several parameters daily. Local Extension offices can assist individuals in accessing this information. Wetland evapotranspiration and lake evaporation have been demonstrated to be roughly equal over a long term (Kadlec 1989). Figure 2-1 illustrates historical averages for lake evaporation.

Water level in a pretreatment lagoon could be lowered below the minimum operating elevation during dry periods due to evaporation and water requirements to maintain wetland vegetation. Alternative water sources may be needed to maintain an optimal level of water in the animal waste treatment lagoon during these periods.

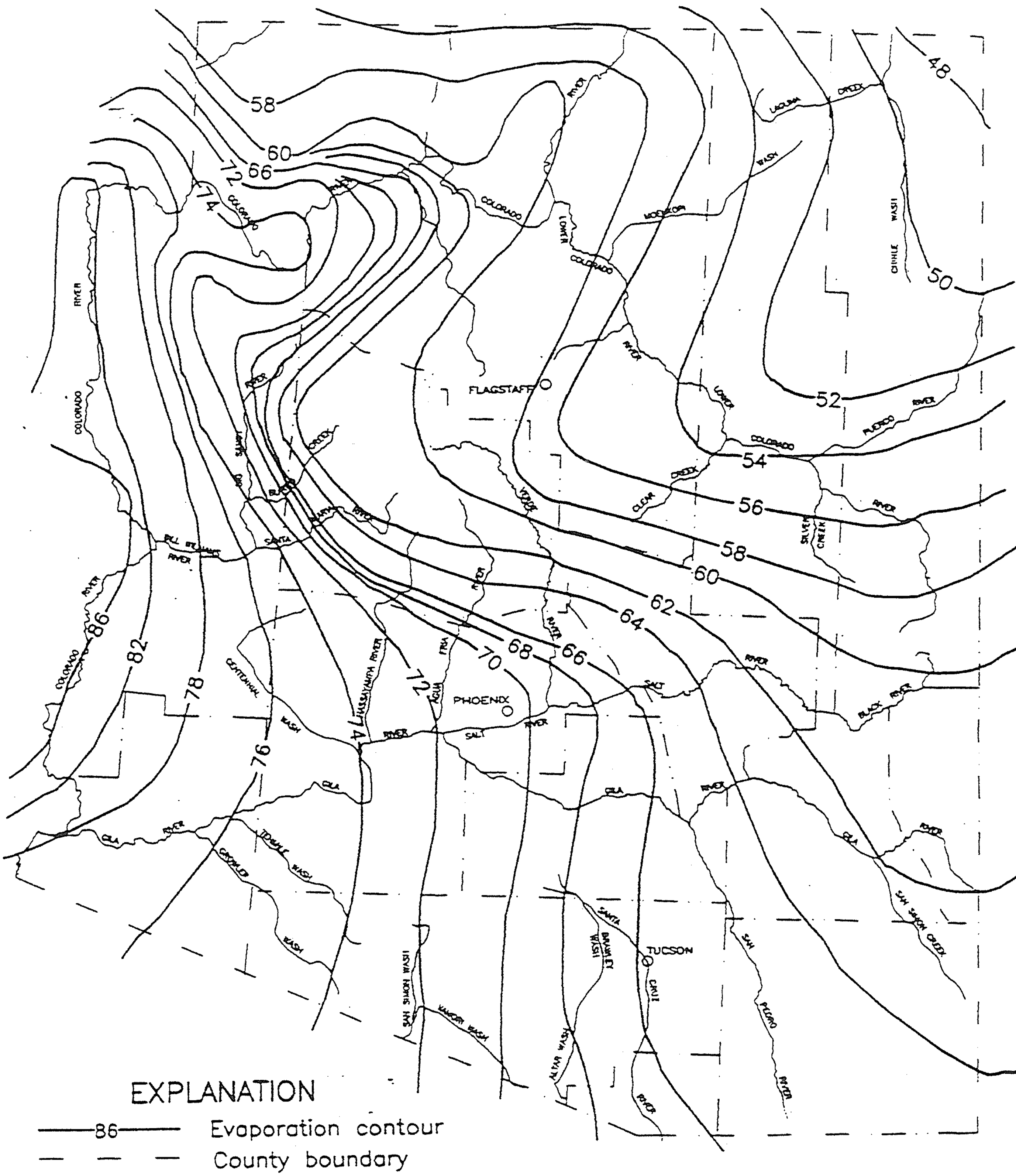

Figure 2-1 - Mean Annual Lake Evaporation
(in inches)

III. Size & Configuration

Two methods are presented which allow for sizing of constructed wetlands. Examples of both methods are located at the end of this chapter. The first, which is called the Presumptive Method, is based on guidelines presented by Dr. Donald Hammer, Project Manager in the Waste Technology Program of the Tennessee Valley Authority. The second method, known as the Field Test Method, is based on an equation presented by Reed, et.al.

Neither of these methods has been thoroughly evaluated for animal waste systems over an extended period of time and at a variety of locations. Initial data for the Presumptive Method appears promising. These methods are considered current technology and will likely be modified and refined as additional systems are installed and monitored as part of the demonstrations associated with these technical requirements.

A. Presumptive Method

This method presumes a certain amount of BOD_5 is produced by the animals and a certain amount lost through the selected treatment method. These values, in combination with an accepted areal loading rate for the constructed wetland, are then used to determine surface area required for treatment.

The areal loading rate using this method will be 65 lbs BOD_5/ac/day. Although this loading rate may eventually be adjusted to reflect different levels of treatment based on climate, no research or field data are currently available to justify use of increased values.

The presumptive method is especially useful when a pretreatment system has not yet been installed and the concentration of BOD_5 in the pretreatment component must be estimated. The presumptive method determines the acres of water surface area required for treatment. To calculate surface area, BOD_5 production estimates should be reduced for climatic conditions. A 75% reduction of BOD_5 due to pretreatment is estimated for warm climates, leaving 25% for remaining BOD_5. The remaining BOD_5 is then divided by the loading rate of 65 lbs/ac/day to arrive at surface area for the wetland in square feet.

Remaining BOD_5 = BOD_5 x 25%

Surface area (ft^2) = (Remaining BOD_5 / 65 lbs) x 43,560 ft^2/ac

Hydraulic residence time is the time allowed or required for wastewater to pass through the constructed wetland to achieve adequate treatment. Hydraulic residence time (t) for the presumptive method is calculated after the surface area (SA) is determined. Additional inputs needed to determine the residence time are daily flow rate (Q), average depth of water (D), and porosity (P).

t= SA x D x P/Q

where:

t = hydraulic residence time, days

SA = surface area of constructed wetland, ft^2

D = flow depth in constructed wetland, ft

Q = flow rate, ft^3/day

P = porosity

Porosity is the ratio of the volume of the constructed wetland occupied by water to the volume of the constructed wetland occupied by plants and water. Watson and Hobson (1989) reported porosity values for selected constructed wetland plants as follows:

Cattails (*Typha*)	= 0.95
Bulrush (*Scirpus*)	= 0.86
Reeds (*Phragmites*)	= 0.98
Rushes (*Juncus*)	= 0.95

Conversely, plant density is 100% minus porosity. For example, plant density for cattails can be calculated in this way:

Plant density = 100% - porosity value

100% - 95% = 5% plant density

B. Field Test Method

The Field Test method uses hydraulic residence time equations in which known (measured) concentrations of BOD_5 can be used. It includes allowance for water temperatures which allows adjustment for climate. The hydraulic characteristics of the constructed wetland are designed to provide the required residence time (t). Hydraulic design and surface area of the constructed wetland is computed using the average depth of flow, and average daily flow rate into the system to find the arrangement that results in the required residence time. The equation includes a reaction rate constant which may not be completely accurate for all locations and site conditions. In addition, the equation incorporates a factor which adjusts for porosity of the cells or volume not occupied by plants. Since plants will occupy from 2 to 14 percent of the water volume, some error is introduced if the plants used in the constructed wetland occupy a different volume than that reflected in the equation. Using this method, hydraulic residence time is first determined and then surface area.

Hydraulic residence time for the field test method involves collecting samples from the lagoon or other pretreatment unit and using known concentrations of influent BOD_5 in the following equation:

$$t = 2.7 (\ln Ci - \ln Ce + \ln A) / 1.1(T-20)$$

where:

t = hydraulic residence time, days

Ci = the constructed wetland influent BOD_5 concentration, mg/l

Ce = the desired constructed wetland BOD_5 wastewater concentration, mg/l

ln = natural logarithm

A = the fraction of BOD not removed as settleable solids near the head of the constructed wetland. (expressed as a decimal fraction, e.g., soluble BOD/total BOD)

T = water temperature, °C

The value used for (A) in many municipal systems is about 0.52. This should be the lower limit for (A) unless research indicates otherwise. If organic material is adequately removed in pretreatment, the value may be increased, but is not to exceed 0.90 (for a waste treatment lagoon designed to USDA NRCS standards preceding the constructed wetland, the value of A may equal 0.90).

The values for (Ci) and (A) should be determined from an analysis of wastewater samples if a pretreatment component is already in place such as a waste treatment lagoon. The sample should be representative of the lagoon supernatant (the liquid throughout the lagoon above the sludge layer).

The samples taken within the pretreatment unit should be composited to represent the whole. Ideally, several representative samples should be collected during different seasons. Due to the variability of the BOD in these systems and to assure adequate safety, the value used for design should be the highest of the test results.

The temperature of the water (T) is controlled by local climatic conditions. The lowest water temperature under which the constructed wetland will be expected to perform should be used for design. In higher elevations, where the constructed wetland is expected to function during winter months, and when there is not complete freeze-up, the temperature of the water under the ice in a constructed wetland can be as high as 5°C. The wastewater may be stored in the pretreatment facilities during these cold season months in order to use a higher value for water temperature and thereby reducing the size requirement of the constructed wetland.

Surface area is then calculated by the following equation:

$$\text{Acres} = \frac{(\text{Flow rate})(t)(\text{depth}/12)}{43{,}560 \text{ sq. ft./acre}}$$

C. Configuration: Length to Width Ratios

Site conditions, such as topography and soil characteristics, will often dictate the configuration and shape of the wetland cells. Where possible, the constructed wetland should be shaped with an overall (combined cell) length to width ratio of 3:1 to 4:1. This overall layout should then be subdivided into parallel cells (see figure 2-2 on page 27), each having a length to width ratio of about 10:1. Dikes will be used to create the division into the parallel cells (see berms below). The effective treatment area is determined by measuring across the cell from the internal side of the dike, not from the top of the dike. As the water level goes down, adequate treatment area is still available if this design method is used (Hammer 1993). The purpose of this division into cells is to ensure uniform flow down the length of the system and, thereby, maintain maximum contact with all the vegetation. It will also facilitate operation and maintenance. Wastewater will be delivered across the width of all the individual cells simultaneously at the same flow rate, if wastewater volume allows.

In the length wise direction, the individual parallel cells may need to be divided into a series; thus, each of the parallel cells will discharge into a downstream cell having the same width. This may be necessary to prevent the water in any one cell from being 6-8 inches (in.) deeper from one end to the other. Operational flow depth ranges from 8 to 30 in. (discussed further in chapter 5). For instance, if the bottom slope of a cell is 0.5 percent and the water depth at the upper end is 4 inches, the depth at the end of a 100 foot cell would be 10 inches. If the required length for the overall system is 400 feet, the individual parallel cells will need to be divided lengthwise to reestablish the needed shallow flow depth. Consequently, a constructed wetland with overall dimensions of 400 feet x 100 feet (note: L:W = 4:1), could contain a battery of four 25 foot x 30 foot primary cells, followed by four batteries of four cells each, or 20 individual cells total. (Note that the length to width ratio of the individual cells in this case was not 10:1. Planners will need to evaluate site specific requirements.)

Cells should number at least 2 in parallel, to allow for maintenance of one without shutting down treatment. Systems in Maryland provide separation of cells for facility wastewater and runoff treatment, independent of one another (Baldwin 1994).

D. Shape

Irregular cell shapes may be considered for aesthetic purposes or to better fit the topography. The widest portion of a cell should be located at the inlet end to facilitate equal flow distribution. Should alternative shapes be desired, cells should have 4:1 length to width ratio to assure adequate treatment (Hammer 1993).

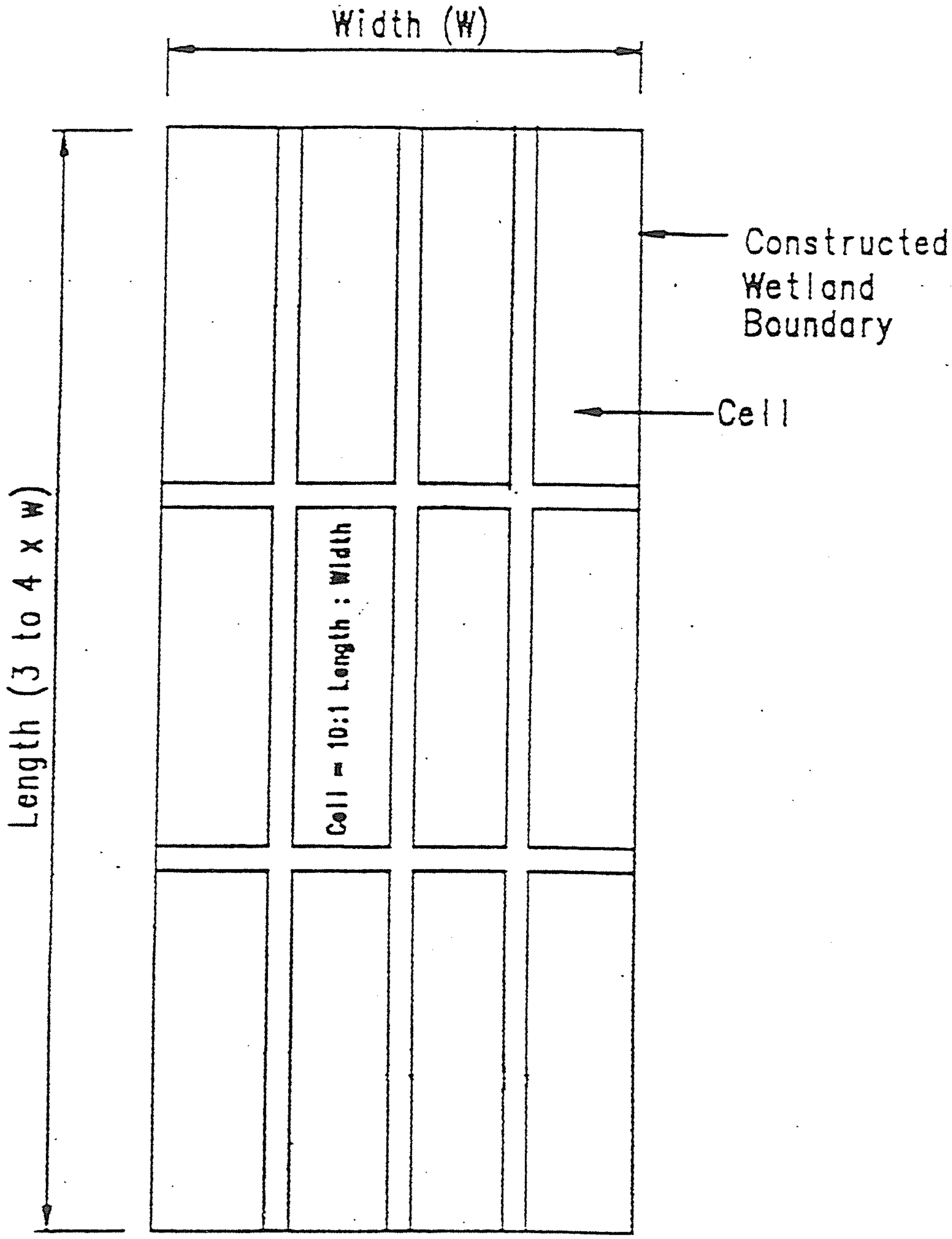

Figure 2-2 Constructed Wetland With Cells

IV. Berms and Retaining Walls

The wetland cells should be surrounded by earthen berms or a retaining wall. The berms retain wastewater in the treatment system and prevent surface runoff from entering the system. According to Tennessee Valley Authority (TVA) guidelines (TVA 1991), the top of the berm/retaining wall should be a minimum of 6 in. above the surrounding ground surface (outside the cell) and accommodate a detritus (organic matter) accumulation rate of 1 in./year. NRCS applications have provided 24 to 36 inches of berm above the planned water depth of the structure (Toor 1994 personal communication).

Earthen berms should be compacted to prevent seepage. If rodent damage is anticipated, vertical welded wire should be included in berm construction.

Consideration should be given to maintenance requirements when planning top width of the berm. If accommodation of a vehicle is necessary, 8 to 12 feet of top width should be allowed. Narrower berms are difficult to construct with a dozer and often must be overbuilt and cut back to size. TVA (1991) recommends exterior slopes of 3:1 and interior slopes of 2:1 or steeper. Slopes should be determined based on erosion potential and maintenance requirements (such as mowing or weed control).

Retaining walls may be an option where space limitations or shallow soils exist. These can be constructed with concrete blocks, cross ties or other materials that are strong and durable. If these materials are not readily available or on hand, their use may be cost prohibitive. Walls should be lined or sealed to prevent seepage (TVA 1991).

V. Points to Apply in Design

The following list summarizes important issues involved in designing a constructed wetland:

A. Pretreatment to reduce concentration of wastes.

B. Water budget assuring maintenance of vegetation.

C. Compute waste calculations and surface area required to treat incoming waste (influent).

D. Design slope and length to width ratio of wetland cells:

1. slope not to exceed 0.5% or 6-8 in. difference in water depth from inlet to outlet end of a cell;
2. combined cell length to width ratio of 3:1 or 4:1; and
3. individual cell length to width ratio of 10:1 where possible.

E. Design for at least two cells in parallel.

F. Berms:

1. 6 in. above surrounding ground surface;
2. 24 in. above planned water depth;
3. consider vehicular traffic requirements and ease of construction in dimensions of berms; and
4. exterior slopes of 3:1,
   interior slopes of 2:1.

VI. Design Examples

Case Study Calculations: Presumptive and Field Test Methods.

PRESUMPTIVE METHOD

SIZING CONSTRUCTED WETLANDS BASED ON AREAL BOD_5 LOADING

Given:

1. A dairy with 800 Holstein cows with an average weight of 1400 lbs. The dairy is located in Central Arizona. Dairy wastewater will be pretreated with an anaerobic lagoon.

2. Allowable BOD_5 loading rate to be constructed wetland is 65 lbs/ac/day.

3. Daily BOD_5 production in the animal waste (from USDA SCS Agricultural Waste Management Field Handbook 1992).

   1.6 lbs BOD_5/1000 lbs AU/day x 2 hr/day in the holding area and milking parlor per 24 hr/day = 0.133 lbs BOD_5/1000 lbs AU/day.

4. Average daily flow through the system is 5350 cu ft/day, which includes washwater and manure from holding area and milk parlor and washwater used to clean pipelines and tanks.

5. Average depth of water in the constructed wetland is to be 8 inches (0.67 ft.).

6. Cattails (*Typha*) and bulrushes (*Scirpus validus*) will be used as the principle wetland plants. These species will typically occupy 5 and 14 percent respectively of the water volume in the constructed wetland (porosity = 95 + 86 /2 or 90%).

Required:

Determine the surface area of the constructed wetland based on the presumptive method, and determine approximate overall dimensions assuming a length to width ratio of 4:1.

Solution:

Determine daily BOD_5 production, where:

BOD_5 = BOD_5/1000 lbs AU x No. of Animals x Average Weight/1000 x days

= (0.133) x (800) x (1400/1000) = 149 lbs/day

All of the feeding and loafing area rainfall runoff will drain into another waste storage pond and will not be allowed into the constructed wetland. A screen is used to separate the solids from the wastewater.

Determine BOD_5 reduction by anaerobic lagoon pretreatment:

Use rate of 75% reduction for warm climate (25% remaining). Lagoon effluent (constructed wetland influent) would then contain:

BOD_5 = (149) x (0.25) = 37.25 lbs/day.

Determine surface area for the constructed wetland:

Allow BOD_5 loading rate of 65 lbs/ac/day (see given)

Water surface area = BOD_5 loading / BOD_5 loading rate = 37.25 / 65 = 0.57 acres = 24,830 sq ft.

Determine hydraulic detention time :

t = surface area x depth x porosity / flow rate

t = 24830 sq ft x 0.67 ft x 0.90 / 5350 cu ft/day

t = 2.8 days

The hydraulic residence time in the constructed wetland must be at least 12 days.

Surface area = (t x flow rate) / (depth x porosity)

Surface area = (12 days x 5350 cu ft/day) / (0.67 ft x 0.90)

Surface area = 106,468 sq ft or 2.45 acres

Determine overall dimensions based of L:W = 4:1

Let W = width of constructed wetland

Let L = length = 4W

Then,

(4W) x (W) = 106,468 sq ft

W = 163 ft

L = 4W = 652 ft

One possible layout for this system could include a set of five cells in parallel providing initial treatment and a set of five additional cells in parallel which receive the waste from the upper set of cells.

The upper and lower groups of cells could measure 33 ft by 326 ft. These dimensions are measured at the bottom of the cells where they intersect the embankment on either side and do not include consideration of dikes of embankments. The actual layout will be governed by the site configuration.

FIELD TEST METHOD

(with part-year discharge)

SIZING CONSTRUCTED WETLAND BASED ON HYDRAULIC LOADING

Given:

1. A swine operation with 2500 head of finishing pigs with an average weight of 160 lbs. The operation is located in Northeastern Arizona. Wastewater from the swine operation will be pretreated with an anaerobic lagoon.

2. Daily flush water is 15 gallon per pig (from the USDA SCS AWMFH 1992) or 37,500 gallons per day.

3. Volume of manure production = 1.0 ft^3/1000 lb AU/day.

4. Annual precipitation is 12 inches.

5. Annual evaporation is 56 inches.

6. Maximum BOD_5 from the lagoon is 100 mg/l.

7. Desired effluent BOD_5 from constructed wetland is 30 mg/l.

8. Average constructed wetland water temperature 15°C based on a March 1 to October 31 discharge from the constructed wetland.

9. Lagoon size is 2 surface acres and 10 feet deep.

Assumptions:

1. The lagoon functions as a facility for deposition of settleable BOD_5. Thus, A = 0.90. A screen is also used to remove solids.

2. Lagoon is designed to not discharge from November 1 to February 28 when constructed wetland is not discharging.

Required:

Constructed wetland size based on part-year hydraulic loading.

Solution:

Determine detention time:

$$t = 2.7\ (\ln C_i - \ln C_e + \ln A)/1.1^{(T-20)}$$

Where $C_i = 1000$ mg/l

$C_e = 30$ mg/l

$T = 15°C$

$A = 0.90$

$$t = 2.7(\ln 1000 - \ln 30 + 0.90)/1.1^{(15-20)}$$

$$t = 2.7\ (6.91 - 3.40 + -0.77)/0.56$$

$t = 16.3$ days

Determine daily flow rate:

Flush water volume = (gal/day) x (days/yr)/7.48 gal/ft^3

= (37,500) x (365)/7.48

= 1,829,880 ft^3/year

Manure volume = ft^3/1000 lbs AU x No. of Animals x Average weight/1000 x days.

= (1.0) x (2500) x (160/1000) x (365)
= 146,000 ft^3/year

Precipitation less evaporation as a volume.

Volume = (rainfall - evaporation)/12 inches/ft) x [(lagoon area) x (43560 ft^2/acres)]

= (12 - 56)/12 x (2 x 43560) = -319,440 ft^3/year

Total Volume = Flush water + manure + precipitation less evaporation

= 1,829,880 + 146,000 + (-319,440)

= 1,656,440 ft^3/year

Daily flow rate = Total Volume/days of discharge

= 1,656,440/(8 months) x (30 days/month)

= 6,902 ft^3/day

Determine surface area required for constructed wetland:

For a constructed wetland with a water depth of 8 inches, the surface area is:

Area = [(Flow rate) x (detention time)]/(depth/12) x (43,560)

= ((16,902) x (16.3))/(8/12) x (43,560) = **3.9 acres**

FIELD TEST METHOD

(with year round hydraulic discharge)

SIZING CONSTRUCTED WETLAND BASED ON HYDRAULIC LOADING

Given:

1. A swine operation with 2500 head of finishing pigs with an average weight of 160 lbs. The operation is located in Northeastern Arizona. Wastewater from the swine operation will be pretreated with an anaerobic lagoon.

2. Daily flush water is 15 gallon per pig (from the AWMFH) or 37,500 gallons per day.

3. Volume of manure production = 1.0 ft^3/1000 lb AU/day.

4. Annual precipitation is 12 inches.

5. Annual evaporation is 56 inches.

6. Maximum BOD_5 from the lagoon is 100 mg/l.

7. Desired effluent BOD_5 from constructed wetland is 30 mg/l.

8. Average constructed wetland water temperature 5°C based on a year-round discharge from the constructed wetland.

9. Lagoon size is 2 surface acres and 10 feet deep.

Assumptions:

1. The lagoon functions as a facility for deposition of settleable BOD_5. Thus, A = 0.90. A screen is also used to remove solids.

2. Lagoon is designed to discharge year-round.

Required:

Constructed wetland size based on part-year hydraulic loading.

Solution:

Determine detention time:

$$t = 2.7\ (\ln C_i - \ln C_e + \ln A)/1.1^{(T-20)}$$

Where C_i = 1000 mg/l

C_e = 30 mg/l

T = 15°C

A = 0.90

$$t = 2.7(\ln 1000 - \ln 30 + 0.90)/1.1^{(15-20)}$$

$$t = 2.7\ (6.91 - 3.40 + -0.77)/0.56$$

t = 38.4 days

Determine daily flow rate:

Flush water volume = (gal/day) x (days/yr)/7.48 gal/ft^3

= (37,500) x (365)/7.48

= 1,829,880 ft^3/year

Manure volume = ft^3/1000 lbs AU x No. of Animals x Average weight/1000 x days.

= (1.0) x (2500) x (160/1000) x (365)

= 146,000 ft^3/year

Precipitation less evaporation as a volume.

Volume = [(rainfall - evaporation)/12 inches/ft] x [(lagoon area) x (43560 ft^2/acres)]

= (12 - 56)/12 x (2 x 43560)

= -319,440 ft^3/year

Total Volume = Flush water + manure + precipitation less evaporation

= 1,829,880 + 146,000 + -319,440

= 1,656,440 ft^3/year

Daily flow rate = Total Volume/days of discharge

= 1,656,440 ft^3 year

Determine surface area required for constructed wetland:

For a constructed wetland with a water depth of 8 inches, the surface area is:

Area = [(Flow rate) x (detention time)]/(depth/12) x (43,560)

= [(4,538) x (38.4)]/(8/12) x (43,560) = 6.0 acres

CHAPTER 3
SOILS

I. Seepage Considerations

Constructed wetlands should provide adequate containment of wastewater within the system to prevent contamination of ground water. The first step in assessing potential seepage is to refer to a published soil survey, if available, at the local NRCS office (see Appendix A). Maps in the survey will identify soils found in the vicinity of the planned structure. The published survey will then identify the nine characteristics listed below relative to the mapped soil. A soil specialist should assess potential variations between the actual site characteristics and the published survey. This assistance can be requested through the local NRCS office. The following data should be evaluated when considering seepage control:

1. Unified classification
2. plasticity index
3. liquid limit
4. permeability
5. bulk density
6. depth to bedrock
7. bedrock type, existence of karst or fractured bedrock
8. water table depth (greater than 6 feet preferred)
9. substrata permeability (<0.2 inches/hour preferred)

This information will help in site selection for the waste system and determination of the need for a liner. Items 1 through 5 are needed to use the Technical Notes identified below to evaluate seepage. Items 6 through 9 impact construction methods and equipment requirements where these factors are limiting. If shallow water tables, fractures, and highly permeable substrata are unavoidable, the following references should be used for seepage control.

Compaction of in situ soils to meet seepage reduction requirements should be investigated. Use of NRCS Technical Note 716 and 717, "Design and Construction Guidelines for Considering Seepage from Agricultural Waste Storage Ponds and Treatment Lagoons" and "Measurement and Estimation of Permeability of Soils for Animal Waste Storage Facilities," respectively, provide guidance in determining when in situ soils will meet seepage control needs. These Technical Notes can be obtained through the local NRCS field office (see Appendix A). If in situ soils are not adequate, clay or synthetic liners may be required. Clay liners should be designed and constructed in accordance with the above mentioned technical notes. Synthetic liners must be strong enough to prevent root penetration and placed deep enough (greater than 12 in.) to allow sufficient vertical root growth. Synthetic liners should be used in accordance with the manufacturer's recommendations.

II. Planting Medium

A. Physical and Chemical Requirements

The existing topsoil is typically removed prior to the construction or installation of a liner. If the topsoil is acceptable, it can be stockpiled and then utilized as the planting medium (bed). The planting medium should be placed on top of the seepage control layer. Equipment should be operated to avoid damage to seepage control layer or excessive compaction of the planting medium.

Published soil surveys are a good source for information about soil characteristics as a growth media. Soil properties that affect suitability as a planting medium are:

Cation exchange capacity - affects exchange and retention of metals and nutrients and should be greater than 15 meq/100 grams of soil.

pH - pH affects availability and retention of metals and nutrients and should be between 6.5 to 8.5.

Electrical conductivity - this is a measure of salinity and should be less than 4 mmhos/cm.

Soil organic matter and texture - affect root growth and pollutant retention.

Sandy soils will have a low retention of potential pollutants and little or no restriction on root growth. Conversely, clayey soils with clay content greater than 45% have high retention of potential pollutants, and restrict root growth. Medium textured or loamy soils are best suited as the plant medium for constructed wetlands as these soils have high retention of potential pollutants, and little restriction on root growth. Consideration should be given to potential rooting depth of selected plants and substrate depth relationships.

B. Preparation for Planting

A light cultivation may improve planting conditions after the planting medium has been spread and brought to grade according to design. Plant seeds into a dry bed and irrigate immediately to saturate soil without leaving standing water. If transplants are to be planted, presoak the cell. Chapter 6 provides greater detail in plant establishment.

The Soil Data List found in Appendix C will assist in compiling soils information to assess seepage potential and suitability as a growth media.

CHAPTER 4
CONSTRUCTION REQUIREMENTS

I. Owner/Operator Responsibilities

The owner/operator will be responsible for selecting a contractor and making contractual arrangements. In addition, the owner/operator will be responsible for administering these arrangements and be ultimately responsible for all phases of the work.

Owner/operators are responsible for obtaining required permits. For detailed information on permits and regulations, refer to Chapter 9 on Regulations. Arrangements for protection or relocation of utilities will be made prior to construction and necessary actions taken to assure safety of people, farm animals, equipment and materials. The owner/operator is responsible for contacting utility companies regarding the protection or relocation of utilities.

II. Planner/Designer Responsibilities

Construction drawings, and construction and material specifications are to be complete and have the detail necessary to install the constructed wetland system. All lines and grades will be clearly noted on the drawings. Other construction requirements and details are to be clearly stated in the drawings and specifications. This includes the location of buried and overhead utilities within the construction limits. A pre-construction conference between the NRCS inspector (if federal assistance is involved), the contractor, and the operator should be held at which time such items as construction details, construction sequence, location of plant materials and borrow materials (if needed), construction survey, and final check-out and inspection items should be reviewed.

The construction inspection requirements should be determined and decisions made about the amount of layout and grade control assistance to be provided. Inspection of constructed wetland elements should be conducted at appropriate times during the construction sequence. Inspection should be conducted of the following elements:

- Clearing, grubbing and grading (minimize site disturbance)

- Seepage control layers, either existing soil materials, compacted in situ soil materials, or clay or synthetic liners

- Selection and placement of soils used for constructed wetland vegetation rooting medium

- Water level control and conveyance devices: Materials such as piping and structures, grades/elevations, and backfilling

- Placement and compaction of embankments or berms

- Establishment of vegetation and survival of vegetation

It is especially important to inspect the grades and elevations for water level control devices as they establish water levels crucial to operation of constructed wetlands.

III. Contractor Responsibilities

The contractor will be responsible for determining the sequence of installation of the constructed wetland elements. Site variables will dictate the sequence but generally the sequence is:

1. Clearing and grubbing of excavation and borrow areas;
2. Excavation, transport, and stockpiling of soil to be used for embankment construction and/or planting medium for constructed wetland vegetation;
3. Excavation and recompaction of soil used for the low permeability clay liner;
4. Installation of synthetic liners;
5. Backfilling and grading of soil used for constructed wetland vegetation planting medium;
6. Placement, shaping, and compaction of soil used for embankments;
7. Installation of water conveyances (pipes, weirs, flumes, etc.) including proper foundation preparation, backfilling, and soil piping prevention features;
8. Installation of erosion control features such as riprap and seeding of embankments and other disturbed areas;
9. Planting of constructed wetland vegetation; and
10. Watering of site.

Site preparation for and installation of water conveyance and level control devices can occur at different times in the construction sequence.

Installation and maintenance of devices and features to control erosion and prevent sediment transport off-site during construction is the contractor's responsibility. Local ordinances should be followed for soil erosion and sediment control.

Equipment used for construction should be carefully selected because of the small areas in which it will work; critical grades that must be constructed; soil compaction that must be accomplished; excavation and transport of soil from borrow locations; and placement of soil materials in small amounts around structures installed in confined areas. Moisture control and compactive effort appropriate to the soil involved will be provided according to requirements stated in the drawings and specifications. Because of the importance of construction to exacting lines and grades, it may be advantageous to the contractor to use laser equipment to maintain grades and elevations.

The **constructed elevation of the flow line will not vary more than 0.12 feet from the lines and grades shown on the construction drawings.** Vegetation in areas that are 0.25 feet or more above the flow line, as constructed, will perform poorly or will not survive. The top of constructed embankments will be as high as the elevations shown on the drawings, never lower. **Grades and elevations of water control devices will not vary more than 0.1 foot from elevations shown on the drawings.**

CHAPTER 5

WATER MANAGEMENT

I. The Role of Water Management

Water level control can be a critical factor in the life expectancy of the constructed wetland. This section reviews structural and vegetative considerations as they relate to water control. However, this is not a comprehensive examination of these considerations. The structures illustrated here are for information purposes only. Available materials and site specific conditions will dictate the inlet/outlet controls for most constructed wetlands. Additionally, the effects of flow depth and flow rates on vegetation will vary depending on species composition and climatic conditions. The following points discuss the role of water level control in the operation and maintenance of a constructed wetland.

1. **Stimulation of processes** - Ability to manipulate water levels and drain constructed wetlands may extend the effective life of the system. "In a natural wetland, hydrology controls nutrient cycling and availability. Under prolonged inundation, many important nutrients are immobilized under reducing conditions in the substrate and unavailable to plants as well as separated from the water column. Periodic drying and oxidation returns these substances to active portions of the cycles within the water column...this is a function of decomposition: anaerobic rates are generally only 10% of aerobic decomposition rates" (Hammer 1992).

2. **Variability of water supply** - During months of high evaporation, it may be desirable to increase flow depth if water supply is adequate over a long term. Evaporative losses in the summer months concentrates pollutants, which may require increases in detention time for sufficient treatment. However, this may be offset by seasonally differing amounts of water used by the facility. Conversely, in some parts of Arizona, winter flow depth of the constructed wetland may need to be increased to allow for ice formation and protection of roots from frost damage. The decrease in temperature and increase in depth result in increases in detention time to achieve desired treatment. This stresses the importance of calculating water use on a monthly basis (see Chapter 2).

3. **Water level manipulation** - Manipulation is necessary for vegetation establishment, root development, and insect control. These factors are discussed in Chapters 6 and 7.

4. **Compensation for changes in hydrologic regime** - In most natural freshwater wetlands, soils in upper portions are organic, resulting in lower hydraulic conductivities (Hammer 1992). In a created system, where Arizona soils have low organic matter, water volume requirements for the wetland may vary/decrease considerably during the first few years as organic matter increases.

5. **Draining for repair and vegetation reestablishment** - Regrading slope of the cell bottom, reestablishing damaged plants, and removing accumulations of detritus all require a surface dry enough to walk or work on.

II. Design Considerations

A. Control Structures

As discussed above, water management affects both structural and vegetative components of a constructed wetland. For design purposes, water level control facilitates maintenance and allows for fluctuations in the availability of water. Mechanisms should be included in design of inlet and outlet structures to control water delivery, distribution, and flow depth. The following discussion of inlet and outlet design is taken, in a large part, from Creating Freshwater Wetlands by Donald Hammer (1992).

Inlet Design:

When using a distributor pipe for wastewater to enter the constructed wetland, the pipe should extend across 90% of the width of the cell. Inlet distributor pipes are generally PVC that is gated or perforated every 6-12 inches. The pipe must be level across the width of the structure. If the pipe cannot be set level directly in the gravel, concrete support stands 12-18 inches above the substrate can be used. Large gravel or rock (3-5 in.) should be placed immediately below and in front of the inlet distributor to reduce erosion and improve aeration. Perforations or gates should be above the water surface for maintenance and aeration. Pipes are generally not less than 4 inches in diameter (Figure 5-1).

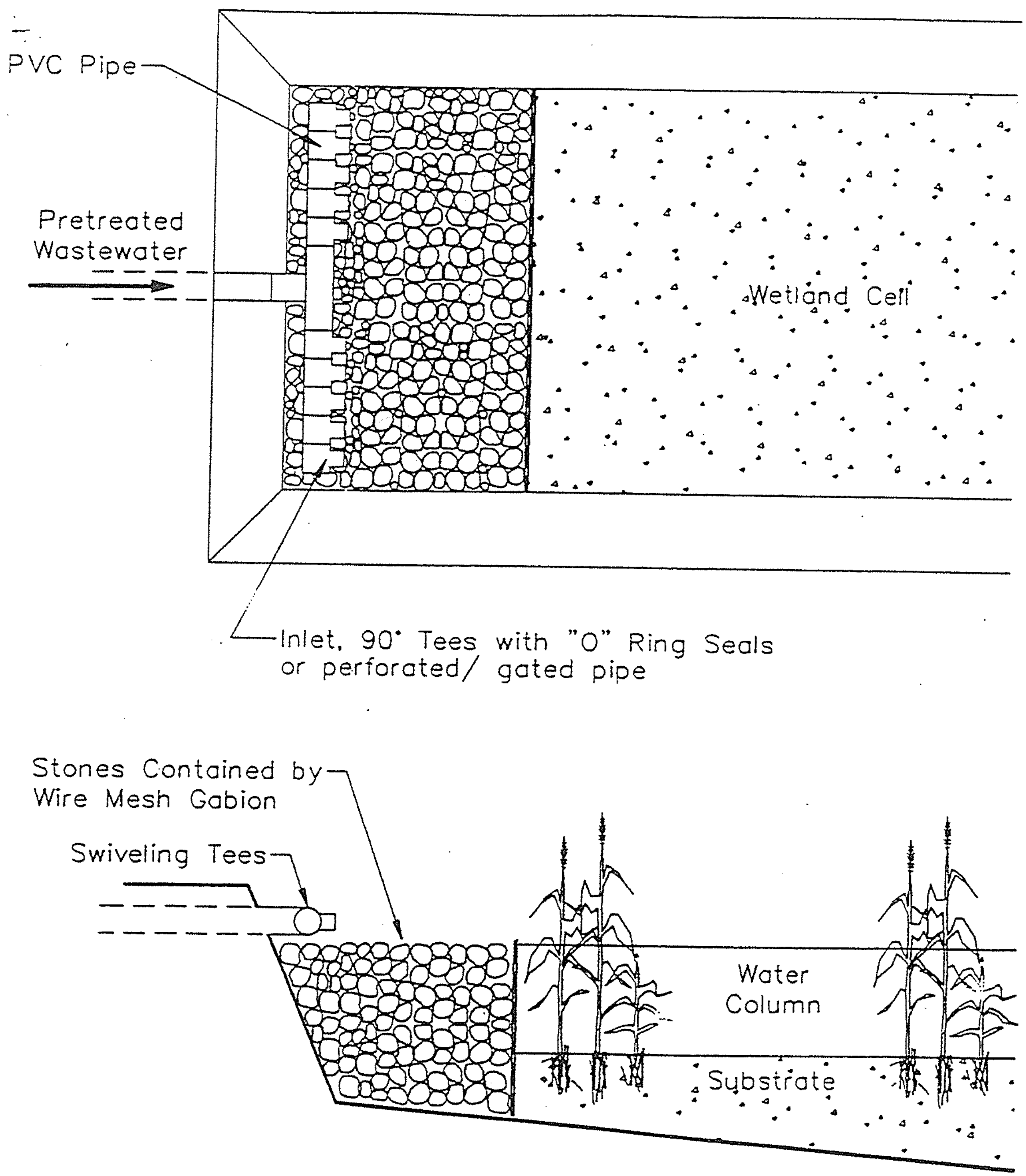

Figure 5-1 - Inlets With Swiveling Tees

Adapted from Cooper, The Use of Reed Bed Systems to Treat Domestic Sewage, 1993.
Moshiri, Constructed Wetlands for Water Quality Improvement, 1993. Pages 208 and 209.
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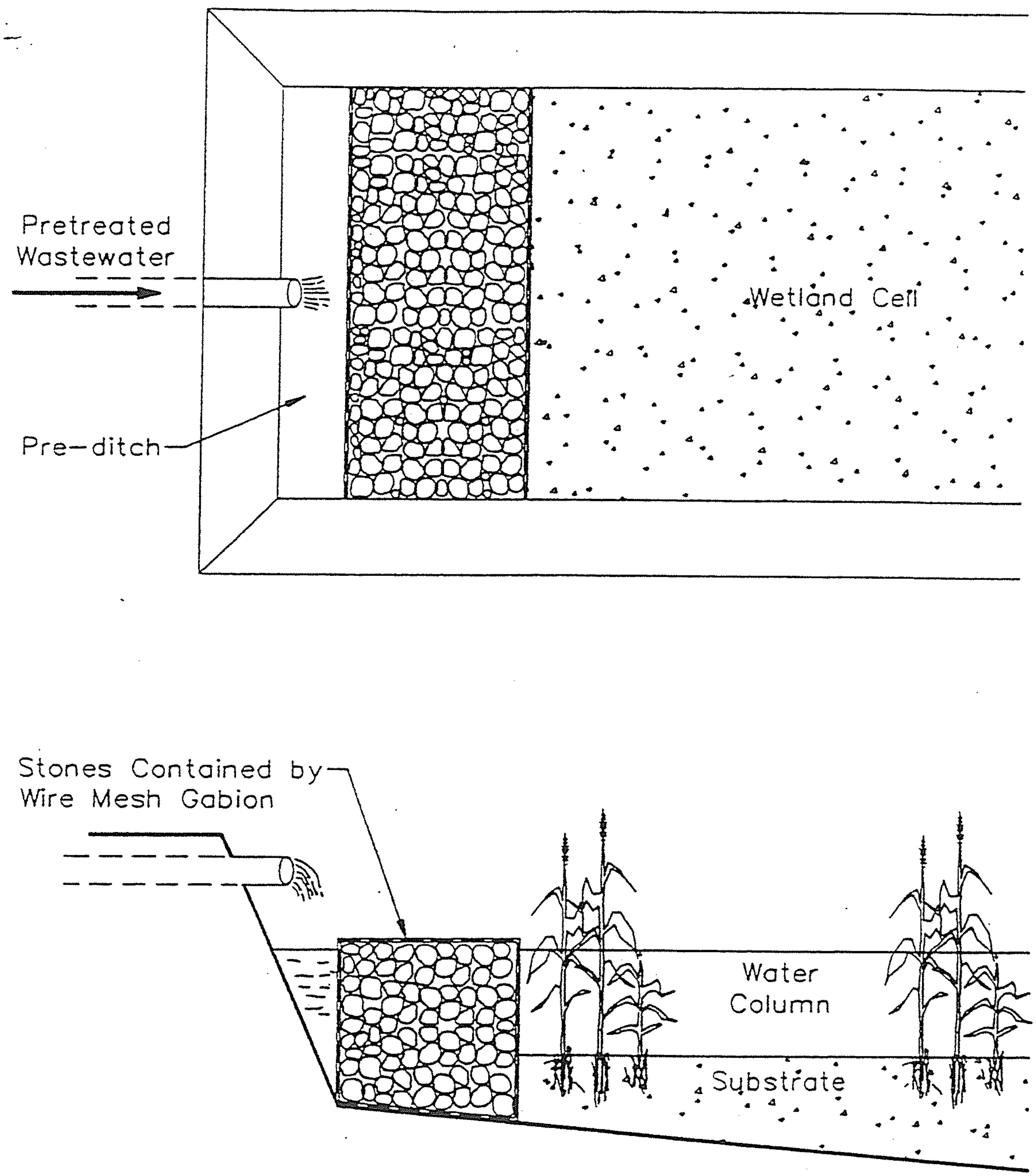

Figure 5-2 - Single Orifice Inlet

Adapted from Cooper, The Use of Reed Bed Systems to Treat Domestic Sewage, 1993.
Moshiri, Constructed Wetlands for Water Quality Improvement, 1993. Pages 208 and 209.
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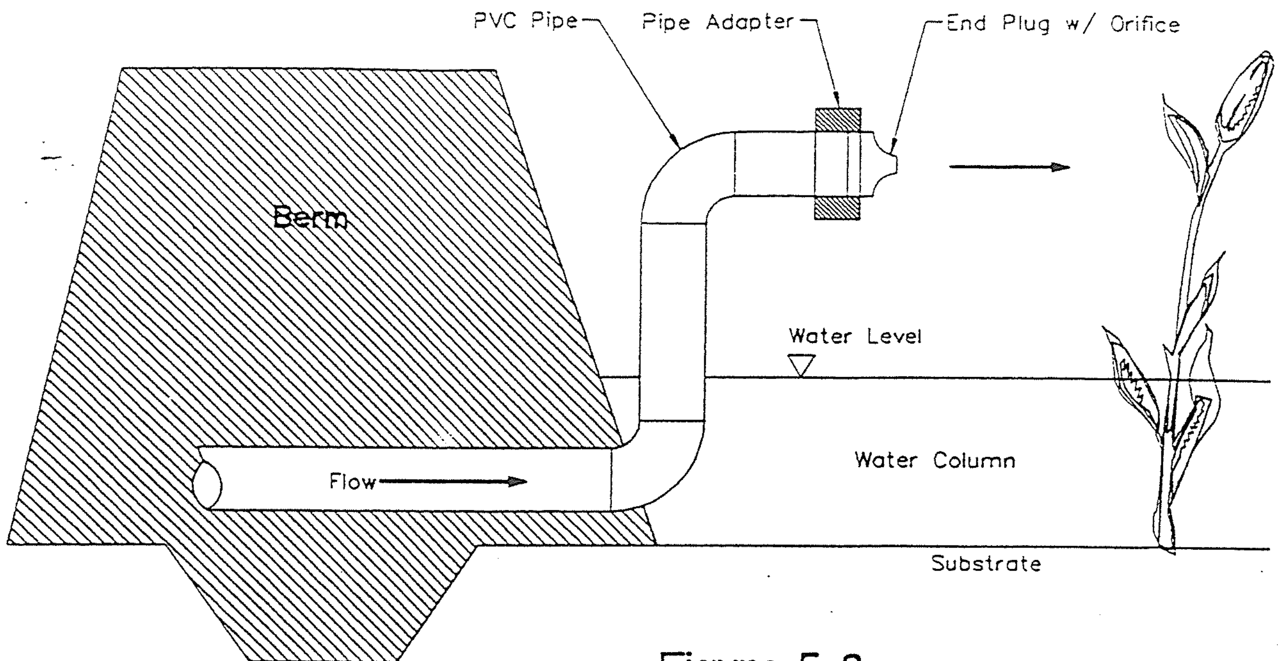


Figure 5-3
Cell Inflow Pipe with Adapter and Orifice

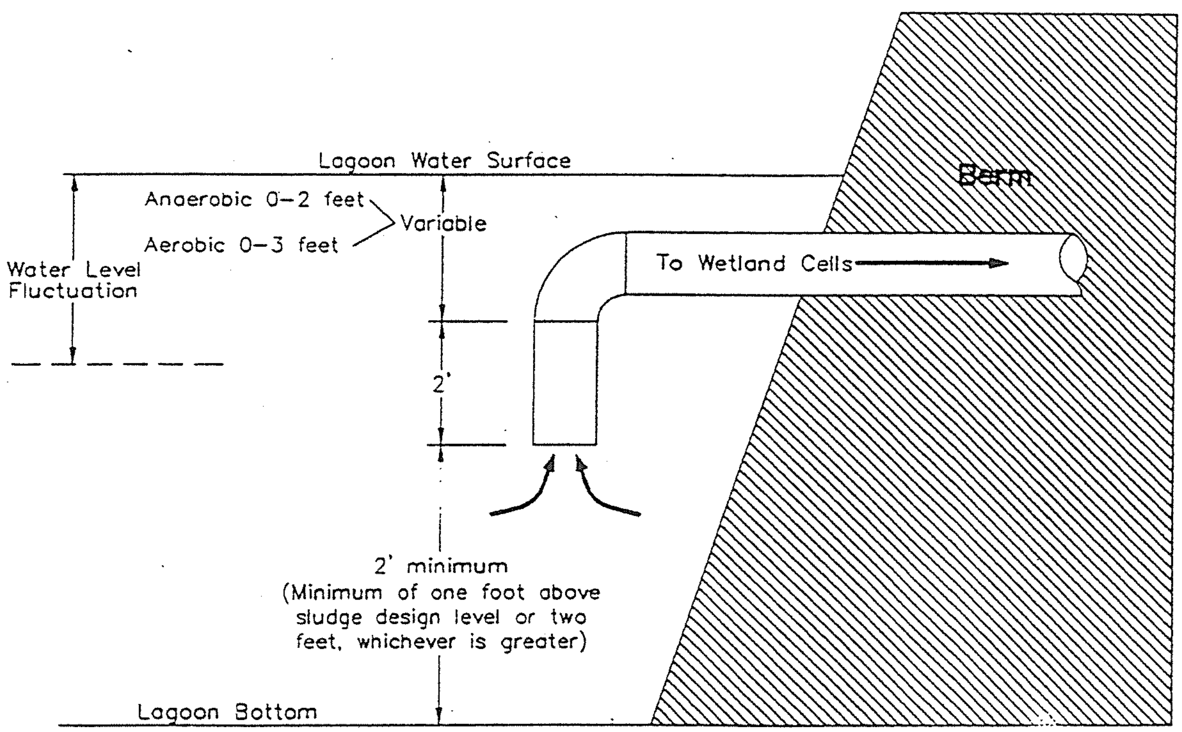
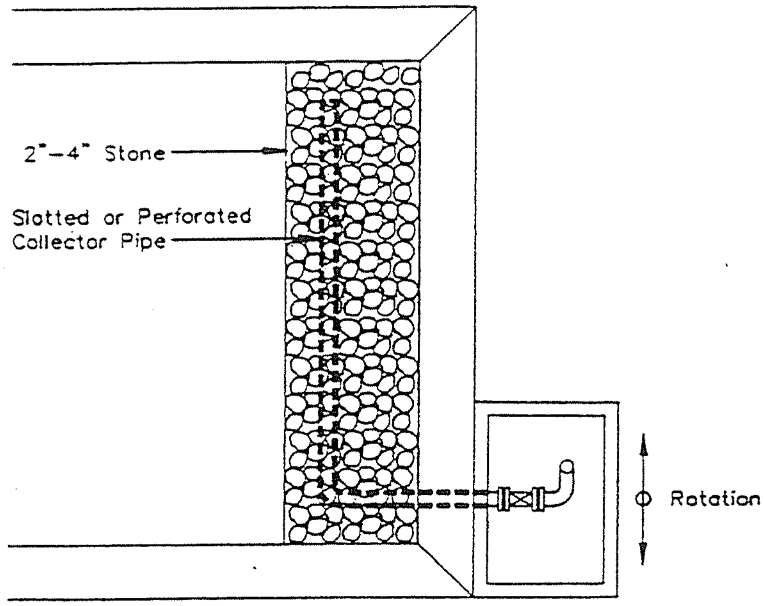
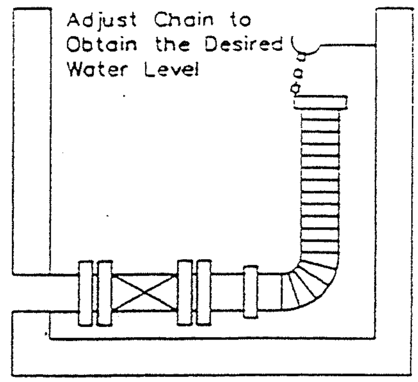


Figure 5-4 - Lagoon Release Turndown to Reduce Debris Content

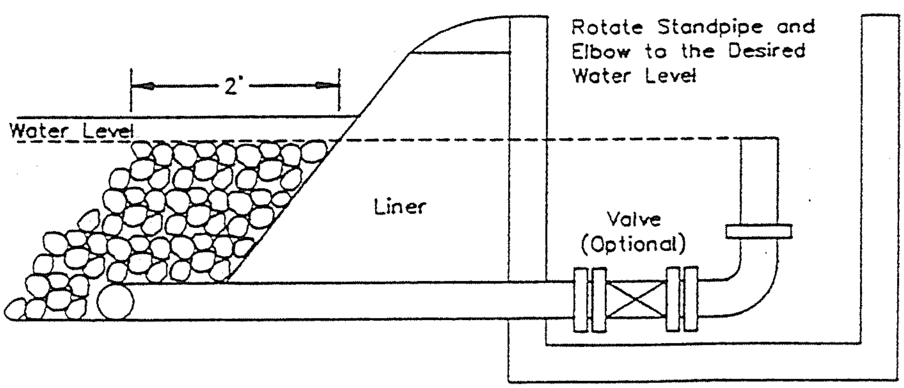
From Ulmer, Cathcart, Strong, Pote and Davis. Constructed Wetland Site Design and Installation. Presented at 1992 American Society of Agricultural Engineers Winter Meeting. Paper No. 92–4528 ASAE, St. Joseph, MI.



Plan View of Outlet
Structure with Swiveling Standpipe



Control Structure
with Collapsible Tubing



Control Structure with Swiveling Standpipe

Figure 5-5 - Water Level Control Structures

From Steiner, Watson and Choate. Tennessee Valley Authority, 1991.
General Design, Construction, and Operation Guidelines:
Constructed Wetlands Wastewater Treatment Systems for Small
Users Including Individual Residences.
Page 10 (Modified from Cooper and Hobson).

If operation pressure or flow rates are incompatible with Hammer's inlet design, an alternative is a single orifice inlet (Figure 5-2 and Figure 5-3). Figure 5-2 illustrates a single pipe inlet which empties into a pre-ditch at the top of the cell. This alternative achieves the distribution of the gated pipe without the material requirements. The pre-ditch could be lined with plastic sheeting or other nonpermeable material, to ensure distribution across cell width, with elevations allowing spill over into rock media. Ulmer (1992) noted single orifice inlets experience clogging problems over time due to algae growth. This was remedied by attaching an end plug with orifice size which maintained sufficient pressure to shear algae growth and minimize clogging (Fig. 5-3).

Whatever system is used, a turndown structure (Figure 5-4) or a screened outlet is recommended on the lagoon side of the inlet pipe to reduce surface crusts or solids from clogging cell inlet or entering the wetland (Ulmer 1992).

Outlet Design

Perforated collector piping at the outlet end of each cell should be slightly below the cell bottom in a gravel lined trench extending 90% of the width of the cell. The discharge pipe may intercept the collector pipe at any convenient location but should terminate in a structure such as a swivelling standpipe (Figure 5-5). Swiveling standpipe or collapsible tubing can then be used for water level management (Hammer 1992).

The swiveling section on the lower side is an L-shaped piece of slightly larger diameter pipe fitted over the smaller pipe with a lubricated O-ring fitting. The pipe section beneath or through the dike should have an anti-seep collar, as for metal culverts or corrugated pipes (Hammer 1992).

In operation, the elbow or L-shaped pipe is pivoted up or down by hand or inserting a short length of wood board into the end of the pipe to increase leverage and carefully rotating the pipe. Raising or lowering the pipe outlet establishes the water level in the wetland pool behind the dike. In the vertical position, it will maintain the greatest depth, whereas horizontally it will drain the pool if the pipe joint is at or below the floor of the pond. Depending on the tightness of the fitting, friction is normally adequate to hold the L-shaped pipe at the desired angle and outlet elevation though, occasionally, it may need to be fastened with a short length of chain (Figure 5-5). A concrete sump should be placed around and below the discharge pipe to control any discharge (Hammer 1992). This well could serve as a small sump for pumping reuse water back through the facility or the waste system. The swiveling pipe is limited to small flow systems which can be accommodated by no larger than a 10-12 inch pipe.

Between cells, the swiveling pipe could serve as a single orifice inlet for the subsequent cell. A concrete sump could also be used between cells. In this case, the inlet for a downstream cell can be tied in at the bottom of the concrete sump. Regulation of flow to each cell in sequence is controlled by adjusting the outlet structure of the upstream cell.

The stoplog structure is another alternative inlet or outlet structure. It operates similarly to an irrigation check, using inserts (boards) to control flows which pass over the top of the structure. Stop logs eliminate clogging problems experienced with pipe and may be a preferred option if operators are more familiar with the concept. A screw valve or irrigation gate can be used for on and off water control. However, these structures are not well adapted to regulating very low flow rates (Ulmer 1992). It may be difficult to maintain the desired water level in the constructed wetland using gates or screw valves.

B. Flow Depth

Recommended flow depths range from 8 inches to 24 inches. In Kentucky, systems generally operate at 10 to 18 inch water depth (Toor 1994 personal communication). The design of the outlet should allow range in manipulation of the water level from draining the cells to variations in water depth not to exceed 24 inches at the outlet end. For maintenance purposes, sloping of the cell bottom facilitates draining and dryout should cleaning or repair be necessary. Slopes that exceed .5% are not recommended; increases in slope cause uneven distribution of water at inlet and outlet ends which in turn will affect distribution of vegetation and treatment level. As noted in Chapter 2 on DESIGN, TVA recommends that the difference between the inlet and outlet depths do not exceed 6 inches (TVA 1991). Thus, slope should be determined after length and operational flow depth are decided. Flow distribution within cells should be occasionally inspected to detect channel formation and short circuiting. Such problems should be corrected by planting vegetation or filling these channels with soil.

C. Discharge

Discharge from constructed wetlands planned, designed and constructed under the guidelines of this document will be confined to a wastewater storage or collection facility. Stored wastewater may be land applied or recycled through the waste management system. Animal wastewater that has been treated in a constructed wetland may only be discharged to a receiving water if permitting conditions are met (see Chapter 9: NPDES and APP programs). The two principle uses for treated wastewater discussed below are: 1) reuse/recycling; and 2) recharge.

Reuse will require installation of a storage or collection structure and pump at the outlet of the constructed wetland. The discharge can be recycled through the waste management system or through the facility in the form of lane flushing or evaporative cooling. Recycling into the facility will require a higher level of monitoring to assure animals will not be exposed to harmful bacteria. In existing CAFOs, recycling will require some level of retrofitting. Recycling treated wastewater through the waste management system will dilute influent BOD_5 and suspended solids, decreasing odor potential and increasing dissolved oxygen concentration and retention times (Steiner 1989).

The acceptability of recharging aquifers with constructed wetland discharges is uncertain, based on current regulatory requirements for recharge projects. Groundwater recharge activities are permitted by two agencies, ADWR and ADEQ. Within the boundaries of an Active Management Area, wetlands treated wastewater stored underground may be recovered at a later date. The recovered water would not be counted against a CAFO's conservation requirements or grandfathered non-irrigation water rights. Due to permitting requirements, associated costs and potential permit conditions, this option can require significant time and effort. Unless streamlined permit processes are adopted, a recharge project for a small system may not be a desirable method of handling discharge from a constructed wetland. For further details on regulatory issues, refer to Chapter 9.

During those times of year when evapotranspiration is high, there may be little or no discharge from the wetland. However, the potential for salinity impacts to wetland vegetation during these periods must be considered prior to installation. It may be necessary to provide supplemental water during these times, or plan for increased seasonal storage to carry the wetland through periods of excessive evapotranspiration.

III. Vegetative Considerations

A. Flow Depth

In constructed wetlands, controlling water levels influences plant survival and desired species composition. Water level is a critical aspect of plant survival during the first year after planting. A common mistake is to assume that all wetland plants can tolerate deep water. Frequently, too much water creates more problems for wetland plants during the first growing season than too little water because the plants do not receive adequate oxygen to their roots (Hollis 1989).

Once established (2 to 3 months), different species of wetland plants can withstand various degrees of flooding depending on when and for how long the flooding occurs. Many wetland emergent plants do best with a period of lower water level during the growing season. During dormancy, drawdown of water level in the constructed wetland is not as important (Hollis 1989). In fact, shallow water levels or saturated substrate during dormancy may freeze root stalks and kill vegetation in extreme winter weather. Water levels should be slowly raised to accommodate ice thickness and reduce frost penetration into the substrate as seasons dictate (Hammer 1992).

B. Flow Rates

Water flow rate can effect plant development, oxygen and nutrient availability, and wetland substrates. Demonstrations have indicated decline in growth with increased depth and more biomass allocated to the roots as velocity increased in shallow water. Increased water flow can also raise oxygen levels in the wetland (Guntenspergen 1989).

Constructed wetland systems do not always have to be operated at the same flow rate. This may improve flexibility in water budgeting. However, the faster the influent enters the cell, the faster it leaves through displacement unless depth is increased, thereby decreasing hydraulic residence time. NOTE: In changing flow rates, ensure that hydraulic residence time of the wastewater in the constructed wetland is sufficient for adequate treatment.

IV. Points to Apply in Water Management

Water management of a constructed wetland involves the following considerations:

A. Maintain saturated substrate during early stages of establishment:

1. 6 to 8 weeks after transplanting, gradually increasing to operational flow depth (refer to transplanting discussion in Chapter 6 on VEGETATION);
2. Introduce wastewater gradually to minimize plant stress.

B. Control of plant communities with water level management:

1. Cattails typically out compete bulrush as water depth increases;
2. Bulrush and sedge may be better suited to shallow perimeter water in a multispecies system; and
3. Some undesirable/unplanted species may be controlled by temporarily increasing water depth in the constructed wetland.

C. Consider monitoring water quality under differing flow rates to determine:

1. A range that will ensure adequate treatment; and
2. Vegetative responses to water quality.

CHAPTER 6
VEGETATION

I. Selection

The role of plants for nutrient uptake in a constructed wetland is secondary to the importance of stem and root systems within the water column. These structures transport oxygen and serve as substrate for bacteria and microorganisms which metabolically improve water quality. Plant litter accumulation (detritus) provides additional surface area for microbial activity. Detritus also serves as a carbon source for reactions which result in nutrient reduction. Priorities for plant selection include structure and pollutant tolerances and operational water depth of the constructed wetland.

A. Availability

Wetland plants can be purchased from nurseries, collected in the wild, or grown for a specific project. For most projects, material collected from the wild is generally preferred. Some literature suggests that plants collected from the wild may be more closely adapted to local environmental conditions than nursery-acquired plants and often initiate new growth more quickly (Hollis 1989). Locally collected plants can also be planted with limited storage if collecting and planting are coordinated. Using commercially supplied plants is advantageous when large quantities of plant materials are needed. However, coordination with suppliers is necessary in advance (6-9 months) in case germination and growth is required. Nursery acquisition also limits potential diversity, as only a few species are commonly available (Hollis 1989).

Disadvantages of local collections are 1) undesirable weedy species may be inadvertently included or rare or endangered species may be inadvertently effected; 2) logistics or difficult collecting conditions may increase costs; 3) plants may not be available because of limited supply, local regulations, or difficult access to land; and 4) plants may be unavailable early or late in the growing season (Hollis 1989).

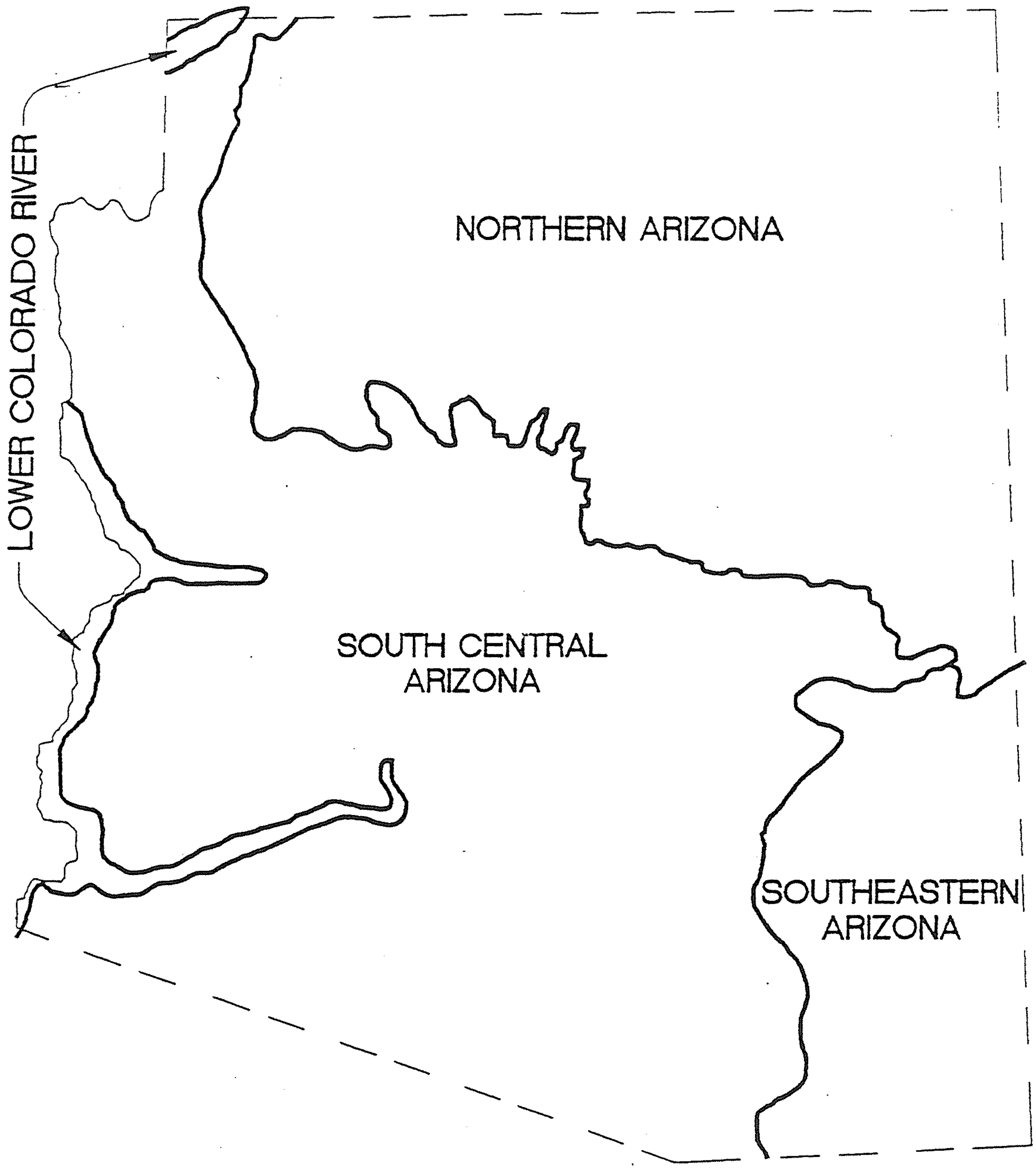
B. Arizona Indigenous Wetland Plants

An evaluation of natural wetlands in Arizona can provide some basic information on native plants with potential application and their characteristics. It is important to remember natural wetlands are likely to receive higher quality water than a constructed wetland. Native vegetation responses to salinity and nutrient levels of animal wastewater are undocumented. The National List of Plant Species That Occur in Wetlands: Southwest (Region 7) (USDI 1988)is a tool for preliminary identification of applicable plant materials. For a closer look at indigenous wetland plants, "*Arizona Wetlands and Waterfowl*" (Brown 1985) divides the state's wetlands into regions and discusses distinctions in climate and vegetation.

An important consideration in using indigenous wetland plants, in addition to those listed above, is utilization by wildlife. Many of the plants associated with natural wetlands in the state have value or importance to water fowl. Although the NRCS Technical Requirements for constructed wetland design discourages wildlife use of constructed wetlands, use by waterfowl may have the benefit of invertebrate control. If reduced wildlife use is desired, a monotypic (single species) plant community with reduced food and cover value could be used; and shoreline and berms should be clear of trees and vegetation. Figure 6-1 and the following discussion is an adaptation of Brown's description (Brown 1985) of environmental settings of Arizona wetlands.

NORTHERN ARIZONA: Generally, the southern boundary of Northern Arizona wetland region includes the top of the Mogollon Rim south and east of a line from approximately Show Low to Springerville, portions of the Coconino Plateau west and south of the San Francisco Peaks and the northwestern extension of the Mogollon Mesa south of Williams. Many of Arizona's swine operations are located in the northeastern part of the state. Elevations are 5,900 feet (1,800 meters) and greater, with natural wetlands occurring largely at elevations between 6,800 and 8,500 feet (2,100 and 2,600 meters).

Most of the natural wetlands in northern Arizona are dormant during the winter. Generally, the growing season extends from April to November. However, this will vary with elevation and local climatic conditions. Common emergent vegetation in northern Arizona includes sedges, rushes and herbaceous aquatic grasses. Cattails (*Typha latifolia*) and bulrush stands are locally well developed below 8,000 feet (2,450 meters). The principal bulrush species



Adapted From Brown, Arizona Wetlands and Waterfowl 1985, University of Arizona Press

Figure 6-1 - Arizona Wetland Regions

are *Scirpus acutus* and *S. pallidus*. Spikerush (*Eleocharis* spp.) is also common. Grasses include mana grass (*Glyceria borealis*) and salt grass (*Distichlis* spp.)

Submerged aquatics may be abundant in the rarely turbid waters. Some of the more valuable species are alpine pondweed (*Potamogeton alpinus*), bladderwort (*Utricularia vulgaris*), water milfoil (*Myriophylum exalbescens*), water buttercup (*Ranunculus aquatilis*), and mare's tail (*Hippuris vulgaris*) (Fleming 1959).

Advantages to using native plants in a constructed wetlands in Northern Arizona include adaptation to temperature and fluctuating water availability.

Considerations in Northern Arizona:

1. Simulate a natural system where possible. Annual water budget for the total waste management system should account for a dormancy period by storing wastewater or reducing inflow rates to the constructed wetland seasonally. This will minimize variations in treatment levels resulting from temperature fluctuations.
2. Planting can be done after the onset of dormancy, or shortly following the last frost as vegetation begins to grow.
3. Managing for ice formation is addressed in Chapter 5. Generally, the goal is to reduce frost penetration into the substrate and thus, reduce vegetation damage.

SOUTH CENTRAL ARIZONA: This region is home to most of Arizona's dairy industry and is, perhaps, the most limited for application of native wetland plants. This is largely due to the lack of natural wetlands which were drastically reduced with impoundment and diversion of water courses, mainly the Salt and Gila Rivers.

Elevation ranges from 328 feet (100 meters) below sea level to 3,936 feet (1,200 meters) above, with average precipitation ranges from 2 to 12 inches (50mm to 300mm). Its frost free period is 250 to 300 days, with temperatures averaging 60 to 75°F (16 to 24°C) (USDA SCS 1981).

A particular area of interest is the middle Gila River where much of the water is some form of wastewater. Saline return flows from the Buckeye and Roosevelt Irrigation District and other water users constitute most of the surface water present in this reach of the Gila.

Brown notes this area once supported pondweed, bulrush, three-square, and cattail (Pulich 1947). Presently, much of the vegetation on the banks of the Gila is saltcedar (*Tamarix chinensis*). It is not unreasonable to expect saltcedar invasion in a constructed wetland if it is located near a seed source.

Picacho Lake, south of Coolidge, is illustrative of potential plant communities of wetlands in the intense climate of the Sonoran desert. This structure receives irrigation water and storm flows. The plant community consists of willows, bulrush, cattail, flat-sedge (*Cyperus sp.*) and saltcedar.

Considerations in South Central Arizona:

1. Climate will allow year round operation if the water budget allows; and
2. Proximity to invaders such as saltcedar.

LOWER COLORADO RIVER: Elevation ranges from 164 feet (50 meters) below sea level to 656 feet (200 meters) above. The landscape is broken by scattered steep-sided valleys and mesas. Average annual precipitation and temperature are 2 to 4 inches (50 to 100 mm) and 70 to 75°F (21 to 24°C), respectively (USDA SCS 1981). Much of the existing riparian/wetland vegetation consists of saltcedar. Below Parker Dam, Brown noted Arrowweed (*Tessaria camphorata*) thickets, interspersed with screwbeans (*Prosopis pubescens*) and western honey mesquites (*P. juliflora*), with cattail lined river banks.

In the Imperial National Wildlife Refuge, Brown noted the banks lined with cane or carrizo (*Phragmites communis*), in addition to the plants mentioned above. Reference is made to "the tall tropic-subtropic cattail" (*Typha domingensis*). Submerged aquatics include spiny naiad (*Najas marina*) and parrot's-feather milfoil (*Myriophyllum brasiliense*). Bulrush or tule (*Scirpus californicus*) is noted as the prevalent seed-producing emergent.

The lower Gila River, below Painted Rock Dam to the confluence with the Colorado River, is predominantly saltcedar; sometimes accompanied by arrowweed, saltbush (*Atriplex* spp.) and seepweed (*Sueda torreyana*). Principal marsh emergent vegetation is cattail with a few areas of three square bulrush. Unlike the Colorado River, the lower Gila is essentially lacking in cane because of the fluctuating and less dependable supply of flowing water. Most waters are also too turbid or ephemeral for a well-developed submergent flora.

Considerations in the Lower Colorado River region should follow those identified for South Central Arizona.

SOUTHEASTERN ARIZONA: Most wetland areas found in this region are between 3,200 and 4,600 feet (1,000 to 1,400 meters). Unlike most of the rest of the state, summer precipitation is more reliable and usually exceeds winter precipitation. Many wet areas in the Sulphur Springs Valley and Willcox area hold water only after an extended wet period. When vegetation is present in these occasionally flooded bottoms, it is predominantly sacaton (*Sporobolus airoides*) and salt grass. Further evaluation of these grasses could prove useful for application when wastewater supply is sporadic and in saline conditions. Treatment of water may be questionable depending on the development of the root system, inundation tolerance and time required to activate the plants.

C. What To Plant

Emergent Plants

Emergent plants are those capable of growing when rooted in flooded substrate but portions of the photosynthetic parts of which must stand above the surface of the water (Chabreck 1988). Cattails, bulrush, and reeds are emergent plants common to all regions identified above and have the most extensive history of use for municipal wastewater treatment in constructed wetlands. The following is a more detailed description of these plants.

CATTAILS (*Typha* spp.) are world-wide in distribution, hardy, capable of thriving under diverse environmental conditions, and easy to propagate (USEPA 1988). They are found in most naturally occurring wetlands and have been documented as tolerant of at least 2.5 day fluctuations in inundation (USDI 1994; Stevens 1991). Throughout the country, cattails are widely used in constructed wetlands. However, some stands established in constructed wetlands in Alabama were decimated by armyworm (Surrency 1993). A more detailed discussion of establishment of cattail in a constructed wetland follows in the discussion of **Establishment**.

BULRUSHES (*Scirpus* spp.) are perennial, grasslike, and grow in clumps. These plants are found around the world in both inland and coastal waters, with varying levels of salinity. These plants tolerate variations in inundation and pH ranging from 4.0-9.0 (USEPA 1988). In Georgia, bulrushes used in constructed wetlands treating post-lagoon wastewater from a swine operation were tolerant of ammonia concentrations of 100-200 ml/l of ammonia during a period from 1989 to 1992 (USDA SCS 1993). In these systems, bulrush is the last plant to go dormant, possibly allowing greater treatment levels for a longer period of time (Surrency 1994, personal communication). Rapid spread of Giant bulrush has allowed planting on six foot spacings, with adequate cell populations as early as six months after establishment.

REEDS (*Phragmites communis*) are tall annual grasses with an extensive perennial rhizome (USEPA 1988). This rhizome facilitates oxygen transfer to the substrate and makes reeds a plant of choice for both FWS and SF systems used to treat municipal wastewater. *Arundo donax* has been used in a southern Arizona constructed wetland used to treat municipal wastewater. It may perform similar to the giant reed found in other regions of the country; however, it does not work well in surface flow systems.

Plant Communities

Consideration should be given to a multispecies treatment system. Diversity within one cell improves habitat and allows operation when one species may be damaged or infested. Cattails may out compete other emergents which require more critical water level management. Plant variation between cells will be easier to manage, but can reduce resilience within a cell should plant damage occur.

D. Aquatic and Other Plants

NRCS Technical Requirements do not provide for the application of floating aquatic plants, largely due to the issue of harvest requirements. However, these systems are addressed here to provide an awareness of the potential for economic end uses of harvested materials.

Floating Aquatic Plants

Much of the application of constructed wetlands technology for municipal waste treatment has involved the use of floating aquatic plants such as water hyacinth and duckweed (*Lemna* spp). The major characteristics of water hyacinth that make it an attractive biological support media for bacteria are an extensive root system and rapid growth rate. The major characteristic that limits their widespread use is their temperature sensitivity (USEPA 1988).

In Arizona, temperature sensitivity limits application to lower elevations in the central and southwest part of the state, unless some type of shelter is provided. Hyacinth trials in constructed wetlands in Malaysia to treat palm oil mill wastewater resulted in considerable reduction in BOD (perhaps attributed to root system) with pretreatment of anaerobic and aerobic digestion. Sensitivity to levels of ammonia has been suggested as a factor which limits plant survival to a few days (Gopal 1987). Water hyacinth have been successfully used in Tucson, Arizona, to treat primary and secondary effluent from a municipal wastewater facility (Karpisack 1994).

In many parts of the world, hyacinth is an invasive weed which chokes canals and waterways. The Arizona Department of Agriculture has classified hyacinth as a noxious weed and regulates its import into the state. It would therefore be important to evaluate the potential impact of hyacinth on local water distribution systems or neighboring natural wetlands and regulations which control its import before selecting this species

Duckweed is more cold tolerant than hyacinth, but sensitive to wind. Duckweed has been documented to tolerate temperatures as low as 45°F (7°C). Below this temperature, the plants survive by sinking to the bottom of the pond and remaining dormant until warmer temperatures return. Duckweed in a waste treatment system can serve to expedite suspended solids removal, begin nutrient removal processes, and curtail algae growth (Karpisack 1994). By forming a cover of duckweed over the pond, oxygen does not readily enter the water. As a result, an anaerobic system is developed which fosters microbial denitrification. However, as hydraulic residence time increases, nutrient and BOD contributions of the system increase and may be exacerbated by the anaerobic situation. Thus, duckweed may be most valuable in the pretreatment component of a waste management system.

Halophytes

Currently, there are no documented studies of livestock wastewaters in Arizona to indicate ranges of salinity. Research into the application of halophytes (salt tolerant or dependent plants) may prove important for application of these systems.

Relatively high salinity levels associated with concentrated animal waste, recycled water, and concentration through evaporation may be the largest limitation of constructed wetland application in the arid southwest. At the Incline Village municipal wetland treatment system in Nevada, the treated wastewater is disposed of primarily through evaporation and transpiration. In this system, evaporation results in increases of total dissolved solids as water passes between cells. However, there is no evidence of a continuing build up in the downstream cells. Apparently, transport of solutes from upstream to downstream cells has reached a balance with other processes (CH_2M Hill).

II. Establishment

A. When To Plant

According to Hammer, most common emergent wetland plants, except cattail, are best planted after dormancy in the fall. Cattail (*Typha spp.*) and, to a lesser extent, *Phragmites*, and most of the grasses and sedges seem to develop and spread faster if planted immediately after dormancy is broken in the spring (Hammer 1992). Observation of native vegetation and review of climatic data (end of frost free period) are useful to estimate planting dates in the spring. *Typha spp.* has been successfully transplanted during late summer in southern Arizona. In general, the planting period for herbaceous vegetation extends from after the onset of dormancy in the fall through spring, as long as adequate time remains before killing frost to permit the new plantings to add new shoots.

B. Planting Methods

The following detailed information on plant establishment is specific to emergents, such as cattail or bulrush. These can be started from seed or transplanted from another site. System applications in Alabama and Kentucky have resulted in guidelines for plant establishment, particularly the emergents listed above (Rash undated; Surrency 1993).

In most systems where emergent vegetation is used, transplants and cuttings are preferred to seed. Transplanting may initially be a longer process than seeding. However, it provides more immediate results and requires less plant source relative to surface area planted. Substrate requirements are addressed in the **Planting Medium** section in Chapter 5 (Soils).

Transplanting

The following process for transplant of cattails, adapted from Rash (undated), is generally applicable to other emergent plants of similar structure.

1. Before planting, pre-soak the wetland cell. This should soften the media, but leave minimal standing water. If hand planting, potable or pretreated water is recommended to avoid contact with the wastewater. Prior to the pre soak, a light cultivation may improve planting conditions.
2. Acquiring transplants:
   a. If a local source of plant materials is available, contact appropriate landowners/managers for permission to remove and Arizona Game and Fish Department (AGFD) regarding endangered plant issues (see Chapter 9).
   b. The main goal when removing cattails is to retain a large portion of the root system. Use of a shovel will reduce potential losses of plants due to separation from roots (by pulling) or inadequate roots to ensure survival. Using the shovel, cut a circle around the plant to loosen roots and gently pull the plant.
3. Tops of plants should be cut to a length of 8 to 10 inches. This should allow enough height to avoid inundation when water is introduced, without so much height that damage may occur from wind throw. Roots can also be pruned to not less than 2 inches.

4. Plants should be transplanted within the same day of removal. Both bulrush and cattail should be planted on 3 foot centers, to a depth of 4 to 6 inches. Refer to table 6-1 if ordering plant materials. The combination of ample roots and appropriate depth will improve stability of the plant.

5. If planting in rows, direction of rows should be perpendicular to inflow and offset every other row. Rows running the length of the cell may result in preferential flow between rows. This reduces the retarding and filtering action of the vegetation as well as hydraulic residence time.

6. Wastewater should be introduced gradually and perhaps mixed to allow acclimation to the nutrient load. In Georgia and Alabama constructed wetlands designed by NRCS, bulrush is planted and soil profile is kept moist but never flooded. Beginning the fourth week after planting, 1 inch of water is added per week. At six weeks, wastewater is gradually introduced (Surrency 1993). Pima County systems were planted into potable water and secondary treated municipal effluent was introduced within a few days after planting, though this is likely less concentrated than pretreated animal wastewater.

Table 6-1 **Population in plants per acre at different spacings. (USDA NRCS - Idaho)**

Plant Spacing	Plants per acre
18 inches	19,321
24 inches	10,816
28 inches	7,921
30 inches	6,889
36 inches	4,830
39.4 inches	3,969

After planting, monitor vegetation for new growth or damage. Disturbance to root structures during transplanting may cause stress because roots are unable to take in sufficient water to offset the high rate of loss from stems and leaves. Once new root development has occurred and water uptake ability is restored, wetland plants can adapt to variations in water availability (Hammer 1992). It may be that transplanted material appears dead, but upon further inspection has new growth from the roots. Once fully operational, continue to visually monitor vegetation for damage. If dead or unhealthy patches of vegetation are found, they should be replanted or concentration of wastewater reduced (Hollis 1989).

Planting From Seed

Seeding the constructed wetland is perhaps the least expensive method of establishment, involving the least amount of time and labor. However, distributing the seed of emergents over a suitable substrate has not been very successful. Some species have relatively low germination rates and most have stratification requirements that are not easily simulated in a constructed system (Hammer 1992). Seeded stands usually take 3 to 4 years to reach high densities.

If seeding is planned, vendors should provide planting instructions. Table 6-2 also illustrates some of the biological characteristics of emergent species.

Table 6-2 **Emergent Aquatic Plants for Wastewater Treatment (USEPA Design Manual 1988)**

Common Names	Scientific Name	Distribution	Desirable Temp., °C	Salinity Tolerance	ph
Cattail	*Typha* spp.	Worldwide	10-30	30 ppt*	4-10
Common Reed	*Phragmites communis*	Worldwide	12-23	45	2-8
Rush	*Juncus* spp.	Worldwide	16-26	20	5-7.5
Bulrush	*Scirpus* spp.	Worldwide	16-27	20	4-9
Sedge	*Carex* Spp.	Worldwide	14-32	–	5-7.5

* parts per thousand

III. Maintenance

A. Water Quality

As discussed earlier, wastewater should be gradually introduced to the constructed wetland to avoid additional stress to the plants. Species of cattail, bulrush, and reed have been documented to tolerate levels of ammonia in excess of 150 ml/l in other states (Surrency 1993; USDA SCS 1993). Regional tolerance differences among these species have yet to be determined. Pretreatment will be necessary to reduce ammonia levels to a point of tolerance for vegetation. Additionally, pesticides or other chemicals that may harm the vegetation should not be directly applied or introduced into the wastewater stream.

Following transplanting, if influent is low in dissolved oxygen, submerged plants may die from inadequate oxygen during winter (Hammer 1992). Consideration should be given to dilution during establishment, should this condition be evident.

As mentioned in the discussion of halophytic plants, salt concentration either within the water column or the substrate has a major influence on plant species selection. Evaporation within the wetland is a concern, as salinity build up over time will kill the constructed wetland. Care should be taken in developing a water budget which ensures seasonal discharge (at a minimum). Future research could utilize saline tolerant vegetation such as saltbush and saltgrass in evaporation beds, with an end use for the vegetation.

Early systems in Arizona will require trial and error to evaluate local species tolerance ranges. Thus monitoring of constructed wetland water quality is encouraged.

B. Temperature and Water Supply

Use of indigenous plants, assuming they can tolerate and successfully treat the wastewater, will assure adaptation to local climates. In the lower elevations of central and southwest Arizona, where the frost free period is 250 to 300 days, cold sensitive plants have greater potential for application. Treatment periods are longer and should provide for more consistency in water quality year round.

Wetzel (1985) notes emergents can substantially lower the water level because of their high transpiration rates. The Incline Village Municipal Wetland in Nevada documented increases of plant evapotranspiration by 20% during summer months (CH_2M Hill). In arid climates, this will be important for development of water budgets. This may be compensated for by increasing storage volume of pretreatment components for winter months or fluctuating flow rates seasonally or a combination of both.

According to Guntenspergen (1989), higher temperatures within thermal tolerances promote increased vegetative production. However, warm water discharge to wetlands throughout the winter may accelerate plant mortality as carbohydrate stores are depleted to maintain higher respiration.

As a precaution, the system should be designed to provide supplemental water. This will provide operators flexibility to evaluate water requirements of the system during early stages of wetland establishment. Care should be taken in providing and withdrawing supplemental water to avoid plant stress due to rapid variation in water quality.

C. Harvest

The need to harvest plants within constructed wetlands varies with the system design. Generally, most nutrient removal occurs microbially, with plant uptake being less of a factor. However, in floating aquatic plant systems, it may be necessary to harvest in order to maintain treatment levels for nutrient removal. Additionally, systems that are experiencing reduced treatment levels due to age may be restimulated by removing mature or dead plant material. Table 6-3, adapted from USDA SCS Agricultural Waste Management Field Handbook, reports the level of nutrient removal that might be attributed to harvesting vegetation. Harvesting can be cost intensive, however there may be opportunities to use harvested materials in a composting operation or for some other end use. Duckweed, harvested by skimming the pond surface, can be air dried or pelletized for an animal feed supplement and could be a valuable protein source (Buddhavarapu 1991). Crude protein content of duckweed grown in municipal wastewater averages 38.7% of dry weight (USEPA 1988). Plant tissue analysis for metals is suggested to assure that uptake and concentration of these elements would not be harmful to consuming animals.

Table 6-3 **Plant nutrient uptake by specified crop and removed in the harvested part of the crop (USDA NRCS AWMFH 1992)**

Plant	Dry Wt. lb/bu	Typical yield/ac plant part	- Average concentration of nutrients % -		
			N	P	K
			------ % of the dry harvested material ------		
Cattails		8 tons	1.02	0.18	
Rushes		1 ton	1.67		
Saltgrass		1 ton	1.44	0.27	0.62
Sedges		0.8 ton	1.79	0.26	
Water Hyacinth			3.65	0.87	
Duckweed			3.36	1.00	2.13
Arrowweed			2.74		
Phragmites (Reed)			1.83	0.10	0.52
Bulrush			-------------- unlisted ----------------		

Though not well documented, the potential for increasing nutrient contribution to the system through detritus (organic material) accumulation should be considered. An alternative to mechanical harvest is to drain and burn the cell(s). This may require reestablishment of vegetation if rhizomes are killed. Additionally, some burning activities require smoke management permits from the ADEQ or local governments (see Chapter 9).

BEFORE HARVESTING OR BURNING:

1. **Provide for alternative storage/treatment of wastewater generated while cell is down.** This can be accomplished easily if a multi-celled wetland is in place, where wastewater can be moved between cells. If the constructed wetland is seasonally operational, consider performing these maintenance activities during dormancy.
2. **Ensure availability of plant sources should revegetation be required.** A convenient and inexpensive option is a neighboring cell in a multi-celled system.
3. **Contact ADEQ and county air pollution control districts well ahead of time regarding burn permitting.** Maricopa, Pima and Pinal counties have established air pollution control districts. ADEQ issues Burn Permits for open burning in all areas of the state that do not have their own air pollution control districts. ADEQ does not presently charge a fee for this permit. See Chapter 9 for contact numbers.

IV. Points to Apply in Vegetative Management

The following points should be considered for successful vegetative management:

A. Select plant species.

B. Determine propagule type:

  1. Vegetative, and/or
  2. Seed.

C. Determine location and spacing:

  1. Vegetative - not more than 1 meter spacing; and
  2. Seed - follow supplier recommendations.

D. Determine time of planting:

  1. After onset of dormancy; and
  2. After last frost (early spring).

E. Determine equipment needed:

  1. Hand labor;
  2. Drill (seed); and/or
  3. Tree planter or tobacco setter (vegetative).

F. Prepare site:

  1. Roughen soil surface - light cultivation; and
  2. Pre- soak.

G. Plant and establish vegetation.

  1. Acquire plant materials; and
  2. If vegetative, plant within 24 hours.

H. Management

  1. Maintain saturated soil, do not overtop plants;
  2. Gradually introduce wastewater; and
  3. Monitor for dead vegetation and replace as needed.

CHAPTER 7

OPERATION AND MAINTENANCE REQUIREMENTS

Operation and maintenance should be a part of the overall AWMS plan, referred to in Chapter 2 on DESIGN. Maintenance has been primarily addressed in Chapters 2,5, and 6 (DESIGN, WATER, VEGETATION, respectively). For additional detail on the items discussed below, please refer to the appropriate section. Additional information in this section includes issues related to pest (mosquito) control not previously addressed.

I. Start-up Phase

The start-up phase should begin immediately after a cell is planted. The purpose of the start-up phase is to establish the plants and ensure their survival, and then acclimate the plants to the wastewater. After a cell is planted, clean water should be added immediately to wet the soil and then the water level should be increased to a depth of 1 to 3 inches. This water level should be maintained until new growth appears on the plants. This period can last from two to four weeks. After good growth occurs and the plants begin to obtain a good height, the water level can be slowly raised to the final design operating depth. At no time should water levels overtop plants. It is important to note that constructed wetlands are living ecosystems and their establishment will need to be assured before treatment of wastewater and pollutant removal will occur.

When the plants are well established at the design water depth, wastewater should be gradually loaded to the constructed wetland at a rate that will not shock the plants. Plant response to the wastewater must be monitored closely during this period. Loading rate may need to be reduced if plant damage is observed.

II. Water Management

During the first winter, water levels should be raised to a depth that will prevent freeze damage to root systems. This may be different from the design operational depth in shallow systems.

Routine weekly inspections are necessary to ensure equal flow from each outlet and inlet distributor pipes. If clogging occurs, the obstruction must be removed. Plant debris obstructing outlet control structures must also be removed. Water levels in each cell should be checked and adjusted as necessary and all piping visually inspected for cracks or leaks. Dikes and flow control structures should be inspected for leaks and any necessary corrective action implemented. Flow distribution within cells should be inspected to detect channel formation and short circuiting. Such problems should be corrected by planting vegetation or filling channels with soil.

The water losses due to evapotranspiration can affect the operation and desired treatment levels during the hot summer months. Evaporative water losses in the summer months decrease the water volume in the system, and therefore the concentration of remaining pollutants tends to increase. Decreased water volume also increases the detention time and may increase the potential for anoxic or anaerobic conditions which will affect constructed wetland performance and could damage vegetation.

Where a waste treatment lagoon is the primary source of wastewater, water level in the lagoon could be lowered below the minimum operating elevation during dry periods. Alternative water sources should be made available to maintain optimum water in the animal waste treatment lagoon during these periods. Consideration should also be given to recycling treated wastewater back through the waste management system. This would help dilute BOD and nitrogen levels entering the constructed wetland.

III. Vegetation

Vegetation should be visually inspected for signs of disease (yellowing/browning, spots, wilting, etc.), insect infestations or stress (stunted growth).

The use of shrubs or trees is dependent on the design of the system. It is important to note that trees can shade out desirable plant species if used in a common cell and may effect integrity of dikes and embankments. Dikes should be mowed at least annually to remove undesirable vegetation.

To date, harvesting of constructed wetland emergent plants has been found unnecessary as is the weeding of invading plants. Water depth manipulation is the least intensive management tool for invasive plants. If harvesting is deemed necessary, refer to chapter 6 for alternatives. Accumulated leaf and stalk litter create a desirable layer of humic materials in the cells within which much of the wastewater treatment occurs. Foot traffic should be minimized and vehicular traffic prevented within the cells because both will compress and damage the humic/compost surface layer.

IV. Pest and Vector Control

A. Water Management

In many constructed wetland ecosystems, pest problems are not significantly greater than those experienced with traditional lagoon or pond systems. Generally, drying up shallow water periodically will control mosquitos and encourage seed production of plants (USDA SCS NEH 1992). Deep flooding and dewatering will strand mosquito larvae (Hammer 1992). Care should be taken not to stress plants and to ensure sufficient hydraulic residence time to treat wastewater.

Routine inspections of plants for insect pests will allow action to prevent build up of pests. Consideration should be given to the use of low growing plant species. This can minimize the potential of plant lodging, which protects larvae from predators such as waterfowl and aquatic insects (Martin 1989).

If water depth and water quality allow (particularly sufficient dissolved oxygen), fish can be incorporated. Fish contribute to mosquito control as predators. However, nutrient contributions of fish waste may require additional treatment as wastewater passes through the wetland.

B. Chemical Management

Commercial larvicides and insecticides used for traditional waste treatment ponds are an acceptable alternative. Products should be used as directed by manufacturer.

C. Other Alternatives

Constructed wetlands designed for subsurface flow exhibit the least potential for insect problems. However, subsurface constructed wetlands typically are designed with a median area of 0.5 ha (1.2 acres) and typically receive flows of 570 cubic meters per day (m^3/d)(0.15 million gallons per day [mgd]) (Knight et. al. 1995). Design parameters which compensate for surface flow tendencies will be necessary before these systems can be recommended.

CHAPTER 8
MONITORING

I. General Requirements

A minimum level of monitoring (defined below) will be required for all constructed wetlands installed with government cost share assistance. The goal of monitoring is to evaluate the potential threat to surface and ground water quality so adjustments to planning and design procedures can be made as necessary. The intensity of monitoring should be based on potential for a successful monitoring program, opportunities, and restrictions related to site variables, availability of equipment and personnel, and funding. Monitoring should account for the quantity of water accommodated by the system and assess the water quality parameters important to system function and environmental protection. It is important to determine reaction rates over a wide variety of conditions, learn how to optimize hydraulics and minimize short circuiting in cells, and to develop projections on the life of the system. Plant materials, operational features, system management, and fish and wildlife factors should also be considered for monitoring.

Sample collection, management and testing are to be in accordance with established EPA procedures or Standard Methods for Examination of Water and Wastewater. Frequency of sampling and testing are to be commensurate with the objectives established in the design of the system. The following will be the minimum treatment objectives based on wastewater concentrations from the constructed wetland:

- BOD_5 <30 mg/l
- TSS <30 mg/l
- NH_3, NH_4, NO_3-n <10 mg/l

Additional treatment objectives may be identified by the operator through water quality analysis of the pretreated wastewater. For example, if the treated wastewater is to be used for fish production, the dissolved oxygen and temperature should included in the monitoring plan. During the design phase, it is important for the operator of the system to identify all treatment objectives to develop a comprehensive monitoring plan.

Duration of the monitoring program will be a minimum of three years from the time operational depth of the constructed wetland is reached. Longer programs should be considered where feasible for operator or where long term contracts are involved.

Data gathered from all sites receiving NRCS assistance in a state will be managed in a single database in the Arizona NRCS state office. The format of the database is to be coordinated with the ADEQ and USDA NRCS.

The purposes and objectives for requiring monitoring of constructed wetlands are to:

a. Characterize the quantity and quality of the inflow water to and the out flow from the constructed wetland basin in order to determine overall performance of the system. An assessment of the potential for discharge and a determination of the need for recycling by land application, recirculation for flushing, or other uses are key features of this item.

b. Define the physical, chemical, and biological processes active in the system in order to refine and develop design procedures and design parameters used to proportion systems needed to meet water quality goals.

c. Evaluate plant material species, as well as planting and management techniques.

II. Surface Water Parameters

The water quantity and quality parameters that need to be determined for constructed wetlands are in the following list. Those parameters marked (**) should be part of all monitoring programs. Testing should be performed on samples taken at the inflow and outflow points to meet the objectives established in design. Where feasible, monitoring should be done on a monthly or biweekly basis. However, due to cost and time constraints, quarterly monitoring should be a minimum frequency. All units will be in mg/l unless otherwise noted.

- Flow in gpm and duration of flow, or flow at time of sampling **
- Total Kjeldahl Nitrogen (TKN) **
- Nitrate nitrogen (NO_3-N) **
- Ammonia nitrogen (NH_3 + NH_4-N) **

- Total Phosphorus (TP) **
- Total Suspended Solids (TSS) **
- Total Dissolved Solids (TDS)
- Fecal Coliform Bacteria (cfu/100 mL) **
- Biochemical Oxygen Demand (BOD_5) **
- Chemical Oxygen Demand (COD)
- Total Organic Carbon (TOC)
- Dissolved Oxygen (DO) **
- pH **
- Electrical conductivity (MMHOS/cm) **
- Redox potential
- Temperature (T) **

Though surface and groundwater parameters are identified for monitoring, it should not be interpreted that the constructed wetland must meet the respective standards for water quality. Unless discharging to a surface water or an aquifer, treatment requirements of wetland are limited to those identified in Chapter 2 (DESIGN) for BOD_5, TSS and Nitrogen.

III. Ground Water Parameters

If a system is designed for recharge to groundwater, state Aquifer Water Quality Standards (AWQS) must be met. These are the most stringent, as they are the same as state drinking water standards. The state agencies (ADEQ and ADWR) will need to assist operators in understanding these requirements and developing a monitoring plan accordingly (see REGULATIONS Chapter 9).

Groundwater monitoring for purposes other than recharge, can be accomplished through extraction of water samples from wells, lysimeters, or subsurface drains. Piezometers or other groundwater level monitoring devices should be used to determine direction of groundwater flow. Background levels of selected ground water constituents should be determined in order to assure that samples collected from around the constructed wetland are minimally influenced by water quality constituents from other sources.

The water quality parameters that should be investigated for groundwater recharge evaluations are listed below. Those marked (**) should be the minimum monitoring performed. State Aquifer Water Quality Standards (AWQS) for the constituents follow.

	AWQS
Nitrate nitrogen (NO3-N) **	< 10 mg/l
Fecal Coliform (cfu/100 mL) **	absence
Chloride (Cl)	
Electrical conductivity (mmhos/cm) **	
Total Kjeldahl Nitrogen (TKN)	
Ammonia Nitrogen (NH_3 + NH_4-N)	

IV. Approaches

Monitoring of water quality should follow a structured plan and schedule and be consistent for credibility of results. To assure collection of accurate information, a few approaches to monitoring are outlined below. These have proven to be effective in other parts of the country and are noted here for consideration.

A. Industry Cooperative

In Kentucky, CAFOs have enlisted support from all aspects of the industry to achieve waste management objectives of phosphorus and nitrogen removal. In a number of cases, constructed wetlands have proven the most economically feasible alternative, which has led to adoption on at least 24 operations. As a new technology to the industry, it could be difficult to ensure consistency in sampling procedures and monitoring to the regulatory community with this many individual operations. Additionally, costs for monitoring are a barrier to some operations. To minimize the expense and assure credible sampling, the industry has formed a cooperative of sorts to conduct monitoring programs for participating facilities. The CAFO managers are freed from the concern of monitoring and the pertinent agencies have greater quality control. Participating in the program are groups such as Farm Bureau, producer cooperatives and other support industries (Toor 1994, personal communication).

B. Research

During early stages of adoption of constructed wetlands technology, there are opportunities to work with State universities and local colleges. Research projects with these institutions can often be funded by outside groups. Working with experienced researchers lends credibility to a project and could result in statewide strategies for monitoring similar projects.

C. State and Federal Agencies

Those agencies (USEPA, ADEQ, and USDA) supporting adoption of alternative systems should help bear the burden of expense and refinement of the technology. States such as Tennessee, South Dakota, and Kentucky acknowledged the need for flexibility in the regulatory community until constructed wetlands are a more conventional alternative. The regulatory agencies in these, and other states, are working with the CAFO operators by:

1. Recognizing treatment levels will fluctuate under differing management and seasons.
2. Recognizing the time requirements for a constructed wetland to be fully operational may be 2 to 3 years (Hammer 1989).

CHAPTER 9
REGULATIONS

Issues such as water quantity, water quality and public health make animal waste management a common concern among a cross section of agencies. The use of constructed wetlands for waste treatment is currently gaining support from federal and state agencies as well as the regulated community to address those and other issues. The degree to which regulatory programs impact constructed wetland projects is site specific and should be included in a preliminary feasibility analysis.

Following are the agencies and their respective programs that could have an interest in a constructed wetland. This chapter is followed by Appendix A which lists agency contact numbers. Although many agencies and programs are identified, bear in mind that not all apply to any given situation and some apply regardless of the type of waste management system.

The following programs and agencies are current as of May 1995. Interested parties should contact ADEQ at least every two years for an update to this section.

I. Federal Programs

A. Environmental Protection Agency

National Pollutant Discharge Elimination System (NPDES) Permit

These permits are issued by the U.S. EPA under Section 402 of the Clean Water Act. Permits are required for facilities which discharge treated wastewater and other pollutants into the waters of the United States. If agricultural waste treatment systems do not discharge into a drainage considered a water of the U.S., NPDES permits are not required. Thus, evaporation, recycling, or irrigation with waste do not require a NPDES permit.

U.S. EPA	(415)744-2125
ADEQ	(602)207-4687

B. Army Corps of Engineers

Dredge and Fill, Section 404 of the Clean Water Act

The U.S. Army Corps of Engineers Arizona Field Office (Phoenix) administers the Section 404 program in Arizona by performing jurisdictional delineations, reviewing applications, and making decisions on permits.

Actions that result in a discharge of dredged or fill material into waters of the U.S., including wetlands, most likely will require a Section 404 permit. **If the project is located outside waters of the United States (typically outside the active channel or outside the 100 year floodplain), the 404 permit is not necessary.** The U.S. Army Corps of Engineers should be consulted to verify if a site meets these criteria. A project may qualify for a nationwide permit, an individual permit, or a Letter of Permission. Section 401 state water quality certification from ADEQ is required prior to issuance of 404 permits from the Corps. EPA issues water quality certification on tribal lands.

U.S. Army Corps of Engineers	(602)640-5385
ADEQ	(602)207-4502

II. State Programs

A. Arizona Department of Environmental Quality (ADEQ)

Aquifer Protection Permit

An Aquifer Protection Permit (APP) is required by ADEQ for a facility that could discharge pollutants to groundwater. Surface impoundments including holding, storage, settling, treatment or disposal pits, ponds and lagoons are considered discharging facilities.

There are two types of permits issued under the APP program, general and individual permits. A general permit is issued by rule if the activity meets the conditions of the general permit. General permits are issued for activities which are large in number, where the cost to issue individual permits is not justified by any environmental or public health concern, where the practices are similar in nature, and when the activities would generally meet the requirements of an individual APP or meet BMPs (DuBois 1992).

A General Permit category has been developed for state-regulated agricultural activities such as the application of nitrogen fertilizer and operation of concentrated animal feeding activities. There is no formal permit application process for facilities covered under general permits, however, the facility must adhere to Best Management Practices for that activity. **As a part of a waste treatment process in conjunction with a CAFO, constructed wetlands are covered under the General Permit.** Best Management practices for CAFOs:

1. Harvest, stockpile and dispose of animal manure from concentrated animal feeding operations to minimize discharge of nitrogen pollutants by leaching and runoff.
2. Control and dispose of nitrogen contaminated water resulting from activities associated with a concentrated animal feeding operation, up to a 25 year, 24 hour storm event equivalent to minimize the discharge of nitrogen pollutants.
3. Close facilities in a manner to minimize the discharge of nitrogen pollutants.

These three practices can be met through the application of guidance practices currently under development by ADEQ in cooperation with the University of Arizona. If a facility is unable to comply with requirements of a general permit, application for an individual permit is required.

ADEQ (602)207-4518

Wastewater Reuse Permits

Reuse permits are required by ADEQ for reuse or irrigation utilizing reclaimed wastewater from wastewater treatment facilities. These permits are issued for five years, with permit conditions based upon current water quality standards for the particular type of reuse involved. No fee is required. Current application of the Reuse Rules views a constructed wetland as a reuse facility only if it is not part of a treatment process. **In an animal waste management system, the constructed wetland is a component of the treatment process, and should not be held to surface water quality standards (except at a point of discharge to a surface water) or require a reuse permit.** Facilities operating with General or Individual APP do not require a reuse permit.

ADEQ (602)207-4687

Air Quality Burn Permit

Air quality permits are required by ADEQ for facilities which have the potential to emit pollutants into the air. ADEQ issues permits for open burning in all areas of the state that do not have their own air pollution control districts. Air quality permits require a minimum of three months to process.

ADEQ (602)207-2337

B. Arizona Department of Water Resources (ADWR)

Underground Storage Facility, Water Storage, and Recovery Well Permits

If a facility within an Active Management Area wishes to recharge water treated in a constructed wetland, an Underground Storage Facility permit and Water Storage permit is required through ADWR. These permits allow permit holders to accrue credits for use (recovery) or sale within the AMA. Wetland treated wastewater stored underground may be recovered at a later date using a Recovery Well permit. The recovered water would not be counted against a CAFO's conservation requirements or grandfathered non-irrigation water rights. Underground Storage Facility, Water Storage, and Recovery Well permits are administered in conjunction with an Aquifer Protection Permit (see above). The AMA office should be consulted if reuse or recycling within the facility is being considered. This will assure operators of how their allotments will be administered under a reuse scenario.

Phoenix AMA	(602)417-2465	Tucson AMA	(602)628-6758
Pinal	(602)836-4857	Prescott AMA	(602)778-7202

C. Arizona Department of Health Services (ADHS)

The Vector and Zoonotic Disease section of ADHS provides technical assistance and support to the public, local units of government and other agencies. Its role is non-regulatory at this time (Freitas 1993).

ADHS (602)230-5917

D. Arizona Department of Agriculture

Pasteurized Milk Ordinance

The Dairy Products Control Office (DPC) enforces the Pasteurized Milk Ordinance (PMO). Operating permits for producers, processors and distributors are administered in accordance with the PMO. Additionally, approval to construct on new or existing facilities is required through the DPC office. Permitting and approvals by the Office is done in consultation with other agencies (Freitas 1993).

ADA DPC (602)542-4189

Restrictions on Reuse Water

The Meat and Poultry Inspection Office of the ADA has responsibility for food safety of meat products and sanitation of slaughtering and processing facilities. In accordance with Federal Regulations, reuse water may not be used in areas where edible products may come into contact with it (Freitas 1993).

ADA MPI (602)542-4971

E. Arizona Game and Fish Department (AGFD)

Plant Material Acquisition/Planning

AGFD should be consulted if local wetland or riparian areas are used for plant material acquisition. This will help to ensure minimal impacts to sensitive areas or species. The agency can also provide information regarding wildlife use of plant materials or proximity of habitats to a planned site.

AGFD (602)942-3000

III. Local Programs

County Agencies

Listed below are contact numbers for counties in Arizona. Listing of a county does not mean regulations exist relative to constructed wetlands. Each county should be contacted individually to determine if there are regulations that apply.

County	Department	Phone Number
Apache	Health Services	(602)337-4364
Cochise	Health Services	(602)432-9488
Coconino	Health Services	(602)779-5164
Gila	Health Services	(602)425-3189
Graham	Health Services	(602)428-1962
Greenlee	Health Services	(602)865-2601
LaPaz	Health Services	(602)669-1100
Maricopa*	Health Services	(602)258-6381
	Environmental Management	(602)273-0895
	Flood Control District	(602)506-1501
Mohave	Health Services	(602)753-0748
Navajo	Health Services	(602)524-6825
Pima	Health Services	(602)740-8631
	Disease Control	(602)740-8315
	Environmental Quality	(602)740-3340
	Wastewater Management	(602)740-6500
Pinal	Public Health	(602)723-9541
	Air Quality Control	(602)868-6760
	Flood Control District	(602)868-6410
Santa Cruz	Health	(602)761-7800
Yavapai	Health	(602)771-3122
	Environmental Services	(602)771-3151
Yuma	Health	(602)329-2220

* Maricopa County Department of Environmental Management, Division of Water and Wastewater Management, Bureau of Vector Control. The Bureau routinely checks waste ponds associated with livestock production, to ensure adequate control of mosquitos and flies. Maricopa County Flood Control District administers programs for activities in flood plains.

Other

Any facility operating within city limits should contact their respective city government to determining programs that apply to a constructed wetland for agricultural waste water treatment.

Appendix A

Sources of Technical and Financial Assistance

Sources of Technical and Financial Assistance:

The following is a listing of agencies which may serve as resources in the planning and implementation of constructed wetlands for agricultural wastewater treatment. Also refer to the Arizona Dairy Producer's Guide to Regulations and Technical Assistance (University of Arizona Cooperative Extension).

USDA Natural Resources Conservation Service
(formerly USDA Soil Conservation Service)
3003 N. Central Ave., Ste 800
Phoenix, AZ 85012-2945

(602) 280-8821 Engineering
(602) 280-8826 Ecological Sciences
(602) 280-8787 Water Resources
(602) 280-8808 Soils

Local USDA (SCS) NRCS field offices can be found in the phone directory under United States Government.

University of Arizona Cooperative Extension
County Extension offices can be found in the phone directory under local listings.

USDA Agricultural Stabilization and Conservation Service
77 East Thomas, Rm. 240
Phoenix, AZ 85012

Cost Share and Conservation Programs (602) 640-5200

Arizona Department of Environmental Quality

3033 N. Central Ave., 5th Floor
Phoenix, AZ 85012

Nonpoint Source Water Quality Programs (602) 207-4518

Arizona Department of Water Resources
500 N. 3rd St.
Phoenix, AZ 85004

Augmentation Grant Program (602)417-2465
Arizona Water Protection Fund (602)417-2448

Arizona State Land Department
1616 West Adams
Phoenix, AZ 85007

Arizona Water Protection Fund (602)542-2697

Appendix B
Design Inventory Worksheets

WORKSHEETS

FOR

PROVIDING (SCS) NRCS TECHNICAL ASSISTANCE

on

CONCENTRATED ANIMAL FEEDING OPERATIONS

Arizona

GENERAL INFORMATION

Type of Assistance Provided

When requested, NRCS may provide inventory, evaluation, planning, application and follow up assistance on concentrated animal feeding operations (CAFOs), including poultry.

Purpose

Every CAFO is different. Although physical facilities, type and number of livestock or poultry are similar, different ownerships typically involve levels and styles of management. Use of a particular site visit worksheet is optional. Worksheets are to be used as a guide to identify information needed for the preparation of a Waste Management Design Report and as a place to record information.

General Information

General information provided per telephone, office visit or field visit may consist of :

A. Available NRCS technical assistance, including CAFO inventory start date and services provided; i.e., Design Report, Agricultural Waste Management Plan, Construction Assistance and follow up.

B. NRCS concerns - soil, water, plants, animals, air and human. Why are we willing to help? Confidentiality is important to both NRCS and the client. We are here to solve problems.

C. Federal cost share available for existing operations i.e., ACP annual and LTA programs, where and when to sign up; FmHA facility loans and tax credits.

D. Guidelines for disposing of manure and polluted effluent as a resource in a manner that does not degrade air, soil and water resources.

E. U.S. Clean Air Act, as amended, and administrated by EPA. The Arizona Department of Environmental Quality (ADEQ) role and administration of the Arizona General Permit for CAFOs, with owner/operator compliance by implementing Best Management Practices (BMPs). Need for individual permit if general permit is not used. Steps to secure and keep valid an individual permit. In general, avoid an individual permit if possible.

Request for Assistance

Upon the CAFO owner or manager requesting assistance, the following information should be known prior to arriving at the CAFO site :

Name of Operation ____________________

Address ____________________

Name of Owner(s) ____________________ Phone ____________

Name of Manager ____________________ Phone ____________

Best time of day to :

Contact Owner by Phone : ____________________

Contact Manager by Phone : ____________________

Visit CAFO Site ____________________

Make Field Surveys With on Site Assistance ____________________

G-1. Type of Operation ____________________

G-2. Size of Operation ____________________

G-3. Changes Proposed ____________________

G-4. Location of CAFO ____________________

More specifically described as being within the ____________ of the ________ of Section ________ Township ____________, Range ________ of the ____________ ________________ Meridian.

G-5. Problems:

Perceived	Identified	By Who	Problem Statement
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____

G-6. Opportunities:

Perceived	Identified	By Who	Problem Statement
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____

G-7. Request area office assistance to:

____ Prepare Design Report or Waste Management Plan.

____ Assist field office staff prepare Design Report or Waste Management Plan.

____ Review prepared Design Report or Waste Management Plan.

____ Assist state office staff to review and approve Waste Management System Design Report or Waste Management Plan.

G-8. Existing and Proposed Site Plan, with Data Sheet(s)

a. General CAFO layout: buildings, feedlots, liquid and solid storage areas and disposal area(s), etc.

Show:

1. Farm boundaries applicable to agricultural waste plan.
2. Disposal area(s).
3. Feedlot area.
4. Storage area for solids and/or effluent.
5. Soil survey with key to soil series and textures.
6. Urban development.
7. Roads, map scale, north arrow, etc.
8. Distance from state or federal highway, nearest town, or other landmark.

b. Detail CAFO facility layout and site plan using drawings and sketches on 8 1/2" x 11" or 11" x 17", plus necessary data sheets show:

1. Building size and use i.e., milking parlor, holding area, feed storage, farrowing, nursery, feeder, finishing, broilers, laying, etc.

2. Domestic and CAFO well(s) with depth, capacity, and casing depth.

3. Feed lot/corrals showing surface drainage direction and slope in ft./ft. or ft./100 ft. (%), and dikes, ditches or waterways to control surface runoff.

4. Solid waste storage areas not included in feedlot/corrals (show dimensions).

5. Liquid waste storage areas and type of facility, i.e., underground concrete tank, excavated earth pond, excavated/embankment earth lagoon, etc., (show dimensions).

6. Sumps, pumps, pipelines, open channels, and non building facilities for collecting and transporting animal waste. Data sheet information should include:

   Sumps - type of construction, size, condition, maximum and minimum effluent (water) surface.

   Pumps - make, model number, impeller diameter, where pump was purchased, time to pump sump from maximum to minimum water surface.

   Pump motor - horsepower, shaft speed in rpm.

   Pipelines - material, size, head available or grade.

   Open channels - material, size, grade.

7. Liquid/solid separating screen, screen tower, and temporary solids storage bunker site.

c. Use dashed lines to show proposed changes on the above maps/drawings.

G-9. <u>Survey Needed</u>

a. Type of field survey

Type of field survey	<u>Check if Needed</u>
1. Pipelines, pumps, etc.	_______
2. Dikes for surface water control.	_______
3. Open channel for surface water control.	_______
4. Storage pond/lagoon(s).	_______
5. Other.	_______

b. Appointment(s) to complete field surveys.

____

GENERAL WORKSHEET DESCRIPTION

G-1. Type of operation - i.e., Holstein Dairy, Beef feed lot, veal calf, farrow to finish swine, finisher swine, chicken broiler, chicken layer, turkey broiler, etc.

G-2. Size of operation - i.e., 800 cow dairy, 12,500 beef feeder, 300 sows, 100,000 laying hens, etc.

G-3. Changes proposed - i.e., expansion to XXXX within five years, abandon facilities by year 2000, install liquid/solid separator screen, expand storage ponds, expand lagoon, etc.

G-4. Location of CAFO
General description - i.e., Ne corner of Southern Avenue and Palo Verde Road, approximately 5 3/4 mile west by northwest of Buckeye, Arizona. i.e., Six miles southeast of Buckeye, Arizona on the west side of Airport Road, 4 miles south of Highway AZ 85.

Legal description - i.e., SW 1/4 of the SW 1/4 Section 28, Township 1 North, Range 4 west of the Gila-Salt River Meridian. i.e., E 1/2 of the E 1/2 Section 25, Township 1 S, Range 3 W of the Gila-Salt River Meridian.

G-5. Problems
Problems may be perceived (suspected) or identified (usually visually) by the owner, manager, ADEQ, SCS, neighbor, passer by, etc. Check whether perceived or identified by who, and briefly state the problem. It is important that all problems, known or perceived, be considered early in the planning process. Redesign and construction delays result when new problems are discovered in an untimely manner. Who perceived or identified a problem indicates who is concerned (operator or public) and perhaps a time frame to correct the situation. This section is a recognition by the owner/manager that changes need to be made to meet personal and/or environmental goals.

G-6. Opportunities

Typically, at least one solution is known for every problem. Check whether a perceived or identified solution is known at this time. Whether or not it is the best or most feasible solution can only be determined by the planning process for a Waste Management System. Associated effects (soil, plants, air, water quality, etc.) often are not addressed. This section identifies solutions already under consideration by the owner/manager, NRCS, or others.

G-7. Approval to be per NRCS National Engineering Manual (NEM) Arizona Supplement AZ 210-500/545. Although very few Arizona Waste Management Systems do not require state office approval, review and approval of all systems can help build confidence. With additional experience and training, some non state office personnel will be delegated approval authority.

G-8. Existing and Proposed Site Plan

During the site visit, identify suggested items so they may be placed on a site plan prepared in the office.

a. Prepare reproducible approximate scale maps, drawings, and sketches on 8 1/2 x 11" or 11 x 17" paper for the design report or agricultural waste management plan. (construction drawings may require more detail.) Blank soil survey aerial photo maps work well where available.

b. Using drawings or sketches, 1" = 100' or greater scale, and 8 1/2" x 11" or 11" x 17" inch paper, show a detailed layout of buildings, pipelines, wells, corrals, waste storage areas, pumps, sumps, and other facilities.

c. Use additional data sheets on SCS-522 or SCS-523 computation paper as needed to clearly display information, i.e., pump data, dimensions of buildings, holding areas, sumps, pipelines, etc.

d. Use dashed lines or other suitable symbols to show proposed facility changes, modifications, or new construction.

G-9. Surveys Needed

This section identifies field surveys needed so they may be accomplished during the visit or at a later time. It is preferred future appointments be set prior to leaving the site.

Date: ___________

DAIRY

Site Visit Worksheet

Operation Represented by: ____

Soil Conservation Service Represented By: ___________________________________

D-1. Confirm or Modify General Information: ______________________________

____

____

D-2. Cow Holding Area:

a. Number of cows milked in a group _______, breed _________________.

b. Average weight of cows being milked is _______ pounds.

c. Number of groups per milking _______.

d. Average time cows are in the holding area _______ minutes.

e. Size of holding area, length _______ ft., width _______ ft.

f. Floor slope (if hydraulic flushed) _______ ft/ft.

g. Are floor sprinklers used to wash udders? Yes _______, No _______

If No go to h.

1. Number of floor sprinklers _______.

2. Capacity of EACH sprinkler head _____ gallons/minute; or sprinkler nozzle size _______ in., nozzle pressure _______ psi.

3. Total length of time floor sprinklers are operated per group _________ minute/milking.

h. Are evaporative cooling mister nozzles used in holding area?

Yes _______ No _______ If No, go to i.

1. Number of mister nozzles used for cooling cows _______.

2. Capacity of mister nozzles _______ gallons/hour.

3. Hours per day operated _______.

4. Months and date of operation _________________ to _________________.

5. Estimate percent of water reaching floor __________%.

i. Cleaning cow holding area between milkings with high pressure hose and nozzle:

1. Cleaning ______ times per day, average time per cleaning ______ minutes.

2. Capacity of hose and nozzle __________ gal/min; or hose valve (faucet) pressure ______ psi, hose diameter ______ inches, hose length ______ feet; or nozzle diameter _______ inches and <u>nozzle</u> pressure _______ psi.

D-3. Milking parlor:

a. Size and configuration of milk parlor ________________________________.
Example: Double 16 Herringbone (32 stalls total).

b. Milkings per day:

_______ times/day _______ _______ through _______ _______
(number) (month) (day) (month) (day)

_______ times/day _______ _______ through _______ _______
(number) (month) (day) (month) (day)

c. Approximate time cows are in milking parlor _______ minutes per milking.

d. Detail washing udder with warm water plus keeping milking equipment and floor areas clean while milking _______ gallons per cow per day.

e. Cleaning milk parlor between milkings with high pressure hose.

Detail cleaning _______ times/day, average time per cleaning _______ minutes.

General cleaning _______ time/day, average time per cleaning _______ minutes.

f. Capacity of nozzle and hose _______ gallons per minute; or hose valve (faucet) pressure _______ psi, hose diameter _______ inches, hose length _______ feet; or nozzle diameter _______ in. and nozzle pressure _______ psi.

D-4. Milk Room, Misc. Milking Equipment, Bulk Tank, and Pipeline Cleaning

a. Measured length and nominal diameter of stainless steel, or glass lined steel pipelines used to carry milk from milk parlor to bulk tank(s).

__________ ft. 1" diameter

__________ ft. 1 1/4" diameter

__________ ft. 1 1/2" diameter

__________ ft. 2" diameter

__________ ft. 3" diameter

__________ ft. ___ " diameter

b. Frequency of pipeline washing ______ times per day.

c. Pipeline washing :

Number of washes with soapy water ______.

Number of rinses with disinfectant ______.

Number of rinses with clean water ______.

d. Stainless steel bulk milk storage tank(s) and capacity:

Number of Tanks	Milk Capacity in Pounds or Gallons
_______	_____ or _____
_______	_____ or _____

e. Bulk tank(s) washing:

Milk Capacity in <u>Pounds</u> or <u>Gallons</u>	Gallons per Wash <u>Auto</u> or <u>Manual</u>	Frequency of Bulk <u>Milk Pickup and Tank Washing</u>
_____ or _____	_____ or _____	______________________________
_____ or _____	_____ or _____	______________________________

f. Hand washing miscellaneous milking equipment usually in sink including rinse water ______ gallons/milking.

g. Washing milk room floors and walls, exterior of bulk tanks, loading slab, etc. _______ gallons/day or: _______ inch nozzle diameter at _______ psi nozzle pressure; and ______ minute washing time/day.

D-5. Estimating Effluent Volumes

Is sufficient information known to calculate (with reasonable accuracy) effluent volume produced? Yes ___ No ___

If no, refer to page on MEASURING EFFLUENT DISCHARGE FROM FACILITIES

D-6. Collection of Field Information for Site Plan

Collection information identified in GENERAL Section G-8 and G-9 to prepare general and detail CAFO facility sketches, site plans, maps, etc.

DAIRY WORKSHEET DESCRIPTION

D-1. Confirm or modify general information - Often times new information becomes available between the time general information and site information are collected. Also, planning changes may result from discussions and site reassessment. Change information on the GENERAL worksheet to reflect current thinking, and make note of changes in this section.

D-2. Cow holding area - the area where groups of cows are held preparatory to entering the milking parlor. Typically, udders, legs, and the underside of cows are washed using impact, rotary, or spray floor sprinklers. The number of cycles and operating time per cycle sprinklers are used for each group of cows varies from dairy to dairy. Control may be manual or by using a preset timer. All waste water volumes eventually need to be expressed in gallons/day , so multiple sources can be added for a total waste volume.

a. the average number of cows in a group is used to calculate the amount of waste water used in the holding area. Cows per group vary from 40 - 100 depending on the size of the milking parlor. Breed will be: Holstein, Guernsey , Jersey, Ayrshire, etc.

b. The average weight of cows being milked is used to estimate the amount of feces and urine deposited in the holding and milk parlor areas.
Typical weights are: Holstein 1400 pounds Jersey 1000 pounds
Guernsey 1100 pounds Ayrshire 1200 pounds

c. The number of groups milked each milking, times the average number of cows per group, will be approximately equal to the total cows being milked. Newly freshened cows (cows having calves within the past ten days) are milked last.

d. The average time cows are held in the holding area indicates the amount of feces and urine deposited in the holding area. Total confinement time in the milking area will be used to calculate the percent of daily urine and feces to be handled by the waste disposal system.

e. The size of a holding area helps identify one dairy from another and provide a check on the number of floor sprinklers. Width is used when designing or evaluating hydraulic flush floor cleaning systems.

f. All holding area floors have some slope for surface drainage. If hydraulic flush floor cleaning is used slope may control depth of flow.

g. Floor sprinklers for washing cow udders, legs, etc.
Use number of floor sprinklers, capacity per sprinkler, and total time of operation to determine volume of wash water in the holding area. WASH WATER VOLUME IN THE HOLDING AREA CONTROLS MOST DESIGNS.

h. Evaporative cooling mister nozzles
Many Arizona dairies use overhead mister nozzles to assist cow cooling in the

holding area. Capacities vary from 2 - 4 gallons per hour with 10 - 30 % of the water reaching the floor. Typically, mister nozzles are operated daylight hours in summer months. Convert water reaching the floor to gallons/day.

i. Cow holding areas may be cleaned one, two, or with three milkings, three times each day. Some dairy operations detail clean once each day with a general cleaning between other milkings. Typically a 50 ft. hose and a 1/2 or 3/4 inch nozzle is used, with cleaning time varying from 10 - 30 minutes each cleaning.

Water used for cleaning holding areas may be estimated by multiplying a known flow rate time. to determine flow rate:
-- time how long it takes to fill a five gallon bucket,
-- calculate discharge knowing nozzle pressure and nozzle size,
-- use the following table knowing dynamic line pressure available at the hose valve or faucet, hose diameter, and nozzle size.
Interpret table values for hose lengths other than 50 foot and nozzle pressures different from 40 and 55 psi.

ESTIMATING

HOSE AND NOZZLE CAPACITY

AND

VELOCITY

HOSE [1] INSIDE DIAMETER inches	NOZZLE Inside Diameter inches	Pressure available to hose [2] 40 psi Capacity gal/min	40 psi Velocity Ft/sec	55 psi Capacity gal.min	55 psi Velocity ft/sec
5/8"	1/4"	10	64	12	77
	3/8"	16	46	18	52
3/4"	3/8"	20	58	25	73
	1/2"	30	48	35	56
1"	3/8"	25	72	30	87
	1/2"	40	64	45	72
1 1/4"	1/2"	45	72	50	80
	3/4"	70	51	80	58
1 1/2"	1/2"	45	72	50	80
	3/4"	80	58	95	69
2"	3/4"	80	58	95	69
	1"	100	41	125	51

1/ 50 foot length
2/ Hose valve or faucet pressure with water flowing

D-3. Milking Parlor

a. Examples of size and configuration of a milking parlor are:

Double 24 Parallel (Total 48 stalls)
Double 16 Herringbone (Total 16 stalls)
Double 8 Side Opener (Total 16 stalls)
40 stall (Total 40 stalls)
30 Stall Trigon (Total 30 stalls)

Herringbone - cows stand with hindquarters and udders facing milker. If feed is provided, feeders are on the outside. Cows enter and exit in groups. Layout may be long and narrow or diamond shaped. This configuration is by far the most popular.

Parallel - cows stand perpendicular to milkers side by side, milking cups are attached to udders between the hind legs. Layout may be long and narrow or diamond shaped. New and remodeled milking parlors use this configuration to milk more cows in a given area.

Side Opener - cows stand head to tail parallel with the milking pit area. Cows access is through a side opening gate. A moving carousel may be used to expand the number of cows being milked. Side opener stalls were popular in the 50's and 60's.

Trigon - cows stand perpendicular or herringbone style along a three sided milking area. Many new milking parlors use this configuration.

Polygon - cows stand perpendicular or herringbone style along a five sided milking area. Many new milking parlors use this configuration.

b. Milkings per day - many Arizona dairy operations milk two times per day throughout the year. Others milk two times per day during summer months, and three times per day fall, winter, and spring; increasing the time cows are in the holding and milk parlor area.

c. the average time cows stay in the milk parlor area contributes to the amount of feces and urine deposited in the milk parlor. Total time (holding and milking) will vary between 45 minutes and one hour 20 minutes per milking for most dairies.

d. Many dairies detail wash teat and udder areas with warm water and paper towel dry before milking cups are connected. Water use varies from selected spot cleaning 1-3 gallons/cow/day where each piece of feces or spilled feed is chased to a drain. In both the floor and external surfaces of milking equipment are kept clean.

D-3. continued ...

e. Milking parlors are cleaned one, two, or with three milkings per day, three times each day. Some dairy operations detail clean once each day with a more general cleaning between other milkings. Typically a 50 ft. hose and a 1/2 in. nozzle is used, with cleaning time varying from 10 - 30 minutes each cleaning.

f. Water used for cleaning the milking parlor may be estimated by multiplying time by a known flow rate. To determine flow rate: time how long it takes to fill a five gallon bucket or calculate discharge knowing <u>nozzle</u> pressure and nozzle size. If the latter method is used, be sure to measure nozzle pressure not line pressure. Nozzle pressure can be measured using a pitot tube and gauge. Hose and nozzle discharge may be estimated using the above table and pressure at the hose valve (faucet) with water flowing.

D-4. <u>Milkroom Equipment, Bulk Tank, and Pipeline Cleaning</u>

a. Stainless steel or glass lined steel pipelines carry milk from each milking position direct to the bulk tank for cooling and storage. Pipelines are cleaned following each milking, using soapy water, disinfectant and clear water rinses. Calculate the volume of water held in pipelines, multiply by the number of washes and rinses, then add 10 to 20 % for flow through (changing from one cycle to another).

<u>Volume of liquid in Pipelines</u>

Nominal Pipeline Diameter	Pipeline Volume in Gallons/ft.
1"	.0394
1 1/4"	.0658
1 1/2"	.0955
2"	.1614
3"	.3660

b. See a. above.

c. See a. above.

d. Bulk tanks are sized by the pounds of milk (8 1/2 lbs./gal.) or by the gallons of milk they hold. Stainless steel bulk storage tanks cool and store milk until it can be picked up by semi-truck for transport to a milk processing facility.

e. Milk pickup may be daily, every day and a half, or every other day. Following milk pickup, bulk tank(s) are cleaned using soapy water, water with disinfectant and clear water. Washing is generally automated but may be done manually.

Bulk Tanks	Total Gallons
Automatic, 3 Cycle Wash	60 - 110
Manual	30 - 50

Show capacity of tank(s) and unit of measure, total gallons of water used, and frequency of bulk tank pickup or tank washing.

f. Miscellaneous milking equipment is hand washed in a sink after every milking. Water used will be about 25 - 50 gallons per milking.

g. Milk room walls and floor, bulk tank exterior surfaces, and outside loading slab cleaning usually takes place once each day, or following each milk pickup. Measure or calculate volume of wash water used. Express amount in gallons per day.

D-5. Collection of Field Information for Site Plan

Refer to GENERAL Sections G-8 and G-9 for information needed when preparing general and detail CAFO facility site plans. Use (SCS) NRCS-522 or (SCS) NRCS-523 sheets for recording information inconvenient to show on a site plan.

Example wastewater calculations for 800 head dairy

Determine:

1. Animal Effluent produced in milking center
2. Wastewater generated in milking center
3. Total daily wastewater produced

Reference	Calculations
#1 - AWMFH Table 4-5	Animal effluent: Feces and urine per cow at 1,400 lb. 80#/day/1,000# or 112#/day 1.3 cu. ft/day/1000# or 1.8 cu ft/day
	Solids - per 1,400# cow 12.5% x 112#/day = 14#/day 12.5% x 1.8 cu ft/day = .23 cu ft/day .23 cu ft/day x 800 cows x 1.25 hr/milking x 3 milking/24hr day = 29 cu ft/day (216 gal/day)
	Liquids - per 1,400# cow 87.5% x 112#/day = 98#/day 87.5% x 1.8 cu ft/day = 1.57 cu ft/day 1.57 cu ft/day x 800 cow x 1.25 hr/milking x 3 milkings/24hr day = 196 cu ft/day (1,472 gal/day)
# 2 - Site visit worksheet	Washing Cows: 56 sprinklers x 5 gallons/minute x 6 minutes/milking = 1,680 gallons/milking group 3 milkings/day x 6 groups = 30,240 gal/day
	Mister/Cooler: 38 misters x 6 gallons/hour x 16 hours = 3648 gallons/day (16 hour run time) x 10% reaching floor = 365 gallons

Site worksheet & page 23 of worksheet

Washing Milking Parlor:

Wash between each 9 cows (3/4" hose @ 55psi)
67 times/day x 2 minutes x 35 gpm = 4,690 gal

Washing Holding Area:
1" hose @ 55 psi = 45 gpm
9 times/day x 10 min. = 90 minutes
90 minutes x 45 gpm = 4,050 gallons

Site worksheet & page 25 worksheet

Milk Room, Bulk Tank, Pipelines:
70' x 1.5" diameter (Return)
70' x 2" diameter
250' x 3" diameter

70' x 0.0955 gal/ft = 7.2 gallons
70' x 0.1614 gal/ft = 11.3 gallons
250' x 0.366 gal/ft = 91.5 gallons
110 gallons

110 gallons at 20% flow through = 132 gallons
1 wash
1 disinfectant
1 flush/rinse

110 gal x 3 cycles = 330 gallons/washing
330 gal/washing x 3 milkings/day = 990 gallons

Milk Room Floor:
10 minutes with 3/4" hose @ 55 psi
35 gpm x 10 minutes = 350 gallons/day

Bulk Tank: (total 4500 gallons storage)
3 times/day x 200 gallons each = 600 gallons

In Between Milking Backflush:
5 gallons/cow x 3 milkings = 15 gal/cow
15 gal/cow x 800 cows = 12,000 gallons

Total Wastewater Produced:

Animal Effluent	
Solids	216
Liquids	1,472
Washing	30,240
Misters	365
Washing Parlor	4,690
Washing Holding Area	4,050
Pipelines	990
Floor	350
Bulk Tank	600
Back Flush	12,000
*Hand Wash/Misc.	100
*Clean Milkroom	350
	55,423 gal/day

* extra

55,423 gal x 0.134 gal/cu ft. = 7,427 cu ft/day

Date: _______

SWINE

Site Visit Worksheet

Operation Represented by: ____

S-1. Confirm or modify general information ____

____

____

S-2. Farrowing Area:

a. Number of farrowing stalls or pens _________________.

b. Average number of sows with or without piglets _________,
average sow weight ______ pounds.

c. Average number of piglets less than 8 pounds ___________,
average piglet weight _________ pounds.

d. Detail cleaning with high pressure hose nozzle ___ gpm; or
nozzle pressure ____ psi and nozzle size ____ inches; or hose
valve (faucet) pressure ____ psi, hose length ____ feet, hose
diameter ____ in and nozzle size ____ inches.

e. Detail cleaning takes ____ minutes twice daily/daily/or every
other day, other ________________________________ .

f. General cleaning in farrowing area:

1. With high pressure hose and nozzle ____ gallons per minute
for ____ minutes ____ per day, ____ every other day,
other ________________________________ .

2. Hydraulic flushing alleys manual ____, automatic timer ____,
12 8 6 4 3 2 1 times daily. ____ not used.

a. Number of alleys flushed ____.

b. Volume per alley per flush ____ gallons, or
depth of flow ____ inches, for duration ____ minutes;
average alley width ____, slope of alleys ____ ft/ft.

S-3. Nursery Area

a. Average number of piglets less than 8 pounds ______,
   average piglet weight ____ pounds.

b. Detail cleaning with high pressure hose and nozzle ____ gpm; or
   nozzle pressure ____ and nozzle size ____ inches diameter; or
   hose valve (faucet) pressure ____ psi, hose length ____ feet,
   hose diameter ____ inches, and nozzle diameter ____ inches.

c. Detail cleaning with hose and nozzle takes ____ minutes, 3 2 1 times daily.

S-4. Feeder Area

a. Average number of weaner pigs 8 - 40 pounds _____,
   average weaner pig weight _____ pounds.

b. Average number of feeders 40 - 125 pounds _____ ,
   average feeder pig weight ____ pounds.

c. Cleaning with high pressure hose and nozzle ____ gpm, or
   nozzle pressure ____ and nozzle size ____ inches diameter; or
   hose valve (faucet) pressure ____ psi, hose length ____ feet,
   hose diameter ____ inches, and nozzle diameter ____ inches.
   Other ______________________________________ .

d. Cleaning takes ____ minutes ____ per day, ____ every other day,
   other ______________________________________ .

e: Hydraulic alley flushing, manual ____, automatic timer ____,
   12 8 6 4 3 2 1 times daily, ____ every other day.
   1. Number of alleys flushed per building ______.
      number of buildings ______.
   2. Volume/alley/flush _____ gallons, or: Depth of flow _____ inches,
      duration _____ minutes; Average width of alley ____, slope of alley ___.
   3. Does hydraulic flush operations use recycled water? yes ____ no ____.

i. Other sources of waste water i.e., leaky pig waterers, faucets, hoses, evap coolers,
   etc. ____ gal/min, or ____ gal/day.

S-5. Finishing Area

a. Average number of finisher pigs 125-250 pounds ____, average finisher pig weight ____ pounds.

b. Open earth lot ____, or concrete slab or floor ____. If earth lot, go to FEED LOTS Worksheets.

c. Cleaning with high pressure hose and nozzle ____ gpm; or nozzle pressure ____, and nozzle size ____ inches diameter; or hose valve (faucet) pressure ____ psi, hose length ____ feet, hose diameter ____ inches, and nozzle diameter ____ inches or Other ____.

d. Cleaning takes ____ minutes ____ per day, ____ every other day, other ____.

e. Hydraulic alley flushing, ____ manual ____ automatic timer
12 8 6 4 3 2 1 times daily, ____ every other day.

1. Number of alleys flushed per building _____; number of buildings _____.
2. Volume per alley per flush ____ gallons; or Depth of flow ____ inches, duration ____ minutes; and average alley width ____ ft., slope of alleys ____ ft./ft.
3. Do hydraulic flush operations use recycled water? yes ____, no ____

f. Other sources of waste water i.e., leaky pig waterers, faucets, hoses evap. coolers, etc. ____ gal/min, or ____ gal/day.

S-6. Gestation Area

a. Number of sows ____, average sow weight ____ pounds.

b. Open earth lot ___ or concrete slab ___. If open earth lot, go to FEED LOTS Worksheet.

c. Cleaning with high pressure hose and nozzle ____ gpm, or nozzle pressure _____ nozzle size ____ inches diameter.

d. Cleaning takes ____ minutes ____ per day, ____ every other day.

e. Hydraulic alley flushing, manual ____ automatic timer ____
12 8 6 4 3 2 1 times daily.

1. Number of alleys flushed per building ____, number of buildings ____.
2. Volume/alley/flush ____ gallons, or depth of flow ____ inches, duration ____ minutes, average alley width ____, slope of alleys ____ ft./ft.

S-6. continued ...

e.- 3. Do hydraulic flush operations use recycled water? yes ____ no ____

f. Other sources of waste water i.e., leaky pig waterers, faucets, hoses, evap. coolers, etc. ____ gal/min or ____ gal/day.

S-7. Boar Area

a. Number or boars ____, average weight ____ pounds.

b. Open earth lot ____, or concrete slab or floor ____. If earth lot, go to FEED LOTS Worksheets.

c. Cleaning with high pressure hose and nozzle ____ gpm; or nozzle pressure ____, and nozzle size ____ inches diameter; or hose valve (faucet) pressure ____ psi, hose length ____ feet, hose diameter ____ inches, and nozzle diameter ____ inches or Other ____ .

d. Cleaning takes ____ minutes ____ per day, ____ every other day, other ____ .

e. Hydraulic alley flushing, ____ manual ____ automatic timer
12 8 6 4 3 2 1 times daily, ____ every other day.

1. Number of alleys flushed per building _____; number of buildings _____.
2. Volume per alley per flush ____ gallons; or Depth of flow ____ inches, duration ____ minutes; and average alley width ____ ft., slope of alleys ____ ft./ft.
3. Do hydraulic flush operations use recycled water? yes ____, no ____

f. Other sources of waste water i.e., leaky pig waterers, faucets, hoses evap. coolers, etc. ____ gal/min, or ____ gal/day.

SWINE WORKSHEET DESCRIPTION

S-1. Confirm or Modify General Information - Quite often new information becomes available between the time general information and more site specific information is collected. Planning changes may result from discussions and site reassessment. Change information on the general worksheet to reflect current thinking, and make note of changes in this section.

S-2. Farrowing areas are compartmentalized metal or wood stalls or pens often with wood floors where sows have their litters. Typically the sow has access to only one half of the 35 - 65 square foot area. Heat lamps are used to warm piglets during cool months. BE ESPECIALLY QUIET WHEN ENTERING THIS AREA.

a. - c. Used to determine amount of feces and urine deposited in farrowing area.

d. - f. Determine flow rate by the time required to fill a five gallon bucket or measure nozzle pressure and diameter, or use hose and nozzle capacity table in the dairy appendix. In section e. and f. circle, cross out, or check the appropriate time period and number of times per day alleys are flushed. Recycled water should not be used in the farrowing and nursery areas.

S-3. Nursery areas are perhaps the cleanest of farrow to finish areas. Fill in the blanks and circle the number of times daily cleaning takes place.

S-4. Feeder areas may contain weaner pigs and feeders. Weaners and feeders are usually separated from finishers due to difference in feed ration.

S-5. Finishing areas in Arizona are typically open sided buildings with concrete floors and flush alleys. Some swine producers use open feed lot or field grazing.

S-6. Gestation area may be within a building with a concrete floor, an open shelter and concrete slab, or entirely open feed lot. Pregnant sows are separated into small groups to reduce fighting and for management purposes.

S-7. Boar areas in Arizona are typically individual pens on open earth feed lots. An open sided building provides shade and shelter. If sows are brought to the boars for breeding, boar feces and urine contribute very little, to the waste management system. Polluted feed lot runoff must be controlled and disposed of properly.

Date: ___________

FEED LOTS

(All Livestock Including Poultry)

Site Visit Worksheet

F-1. <u>Feed Lot Area</u>

a. Number, kind, and average weight of livestock:

______ Dairy Calves	______	lbs.	______ Swine Sows	______	lbs.
______ Dairy Heifers	______	lbs.	______ Swine Boars	______	lbs.
______ Dairy Cows	______	lbs.	______ Swine Finishers	___	lbs.
______ Beef Calves	______	lbs.	______ Lambs	______	lbs.
______ Beef Feeders	______	lbs.	______ Sheep	______	lbs.
______ Horses	______	lbs.	______ Turkey Broilers	___	lbs.
______ ________	______	lbs.			
______ ________	______	lbs.			

b. Feedlot surface area ______ acres.

c. Surface drainage direction & slope. ________________________________

F-1. continued ...

d. Are concrete pads installed on the livestock side of feeders or managers?

Yes ____ No ____; If yes, what is the number, length, and width of each pad? ______________

______________________________ Is the area included in b. above?

Yes ____, No ____

e. Percent (or area in acres) and type of feed lot surface:

concrete _______, asphalt _______, earth _______.

f. occupation period(s) _______ all months of year, or

_______ _______ to _______ _______

Month Day Month Day

g. Is unpolluted storm runoff up to the 25 year - 24 hour event excluded from the feedlot by dikes, ditches, natural slope, or other physical barriers?

Yes _______ , No _______

If no, what is the additional watershed area _______ acres, watershed soil(s) _______ , watershed cover ______________ ?

h. Total watershed area contributing to polluted runoff is _______ areas.

i. Is surface drainage from feed lot areas controlled? Yes _______ No _______

If yes, how? Waterways ____ , ditches ____ , dikes ____ , or berms ____ ; storage pond or lagoon ____ .

j. Solid waste from feedlots is removed continuously _______ , monthly _______ , bi-monthly _______ , semi annually _______ , at least annually _______ .

FEED LOT

WORKSHEET DESCRIPTION

Feed lots are used for many purposes and for all types of livestock (including poultry). In all cases the soil surface is absent of vegetation. Soil surface compaction and a biological seal 14 - 18" below the soil surface develops to limit the movement of polluted water downward. Polluted surface runoff resulting from precipitation up to the 25 year - 24 hour event should be controlled and disposed of properly. When estimating runoff use NRCS curve number 97 for concrete or asphalt areas, and curve number 90 for earth feed lots.

Minimize polluted water volumes by excluding irrigation tailwater and clean surface runoff from entering feed lot areas. Wide low elevation dikes or berms and wide shallow waterways can be very effective. Often times the same area can contain sight and sound barrier plantings and/or roadways. Safe disposal of diverted or intercepted water is essential.

When removing dry manure from feed lot surfaces, leave 1/2 to 1 inch of dry manure to minimize disturbing the highly organic compacted earth surface seal. Coupled with a biological seal that develops under anaerobic conditions under feed lots 14 - 18" below the surface, downward movement of polluted effluent is virtually eliminated.

Uncontrolled polluted surface runoff from feed lots can be a prime source of ground water nitrates. Collection and storage facilities should be designed, constructed and operated in a manner to minimize seepage. Store polluted runoff in or on sealed areas only. Disposal should be by irrigation with IWM or evaporation. Temporary storage on lower elevation feed lot areas using wide low elevation berms or dikes may be most economical.

F-1. <u>Feed Lot Area</u>

a. Number, kind, and weight of livestock controls the amount of feces and urine deposited on the feed lot area.

b. Feed lot area is used to calculate polluted surface runoff.

c. Record or show on sketch feed lot surface drainage direction and slope in ft/ft or ft per 100 ft (%).

d. Some feed lots have concrete or asphalt pads in front of feed mangers to improve livestock traffic and save feed. If so, surface runoff will be slightly higher. Use runoff curve number 90 for unsurfaced areas and runoff curve number 97 for surfaced areas.

e. Use percent concrete plus asphalt and percent earth to establish a weight curve number for estimating feed lot runoff.

F-1. continued ...

f. Occupation period is used to estimate feces and urine deposited on the feed lot area.

g. Non diverted clean water becomes polluted upon entering feed lot areas. Use dikes, berms, ditches, waterways and natural slope to intercept and divert clean runoff. Minimum design capacity of polluted and clean runoff facilities (ditches, dikes, storage ponds, etc.) is runoff expected from the 25 year - 24 hour storm event.

h. Total watershed area contributing to polluted runoff is the sum of items b. and g. above.

i. Feed lot surface drainage is controlled only if collection, transport, and storage facilities are confined and include seepage control.

j. Solid waste in feed lot areas should be removed at least annually. Livestock health and fire may be the biggest hazard.

Date: ___________

SOLID WASTE COLLECTION AND STORAGE

(All Livestock Including Poultry)

Site Visit Worksheet

W-1. <u>Solid Waste Storage Facilities</u>

a. Are solid waste collection and storage areas considered part of the feed lot surface? Yes ___ No ___ If yes, go to EFFLUENT COLLECTION AND STORAGE

b. Dimensions of solid waste storage area existing ________ , proposed ________ , length _______ feet, width _______ feet, or describe _________________________
____

c. Is unpolluted storm runoff up to the 25 year - 24 hour event excluded from solid waste storage areas by dikes, ditches, natural slope, or other physical barriers? Yes _______ , No _______

If no, what is the additional watershed _______ acres, watershed cover _________?

d. Is surface drainage from the solid waste storage area controlled? Yes ___ No ___. If yes, how? ____

e. Solid waste from feedlots is removed continuously _______ , monthly _______ , bi-monthly _______ , semi annually _______ , at least annually _______ .

f. Solids are ultimately disposed by:
spreading on irrigated cropland _______ , off farm sales _______ ,
fed to livestock _______ .

SOLID WASTE COLLECTION AND STORAGE

WORKSHEET DESCRIPTION

W-1 Solid waste collection and storage facilities consist of conveyance and storage facilities having sealed surface areas where polluted runoff is controlled. Solids consisting of livestock manure, wasted feed, urine, and bedding (if used) may contain up to 85% moisture, and be handled with normal front loading equipment. Angle of repose for dry stacked solids may vary from 1:1 to 1 1/2:1 (horizontal:vertical). Wet solids and slurries may be as flat as 10:1. Rapid surface drying minimizes fly propagation.

a. Environmentally, feed lot areas are best for solid storage. Downward water movement is limited and polluted surface runoff can be included with feed lot runoff facilities. Maximum drying and nitrogen reduction may also take place. Fly propagation is minimized. Polluted runoff collection facilities may consist of broad low elevation dikes or berms and broad shallow waterways, a part of the feed lot surface.

b. Solid waste storage areas should be defined areas constructed to minimize environmental degradation.

c. National criteria (EPA and NRCS) require clean and polluted water (effluent) runoff facilities be designed and constructed to control runoff expected from at least a 25 year - 24 hour storm event. (Runoff events with equal or greater than a 4% chance of occurrence in any given year). In most cases it is highly cost effective to exclude clean water from entering a waste management area where it too becomes polluted. Use runoff curve number 90 for unsurfaced areas and runoff curve number 97 for surfaced feedlot areas.

d. Surface drainage facilities consist of grading surface areas and using ditches, dikes or berms, waterways, pipelines, sumps, etc., to collect, confine and dispose polluted surface runoff.

e. Solid waste should be removed at least annually to minimize dust, fire, and livestock health problems. SOLID WASTE IS A RESOURCE and maybe used as a soil amendment or fertilizer. With management, screened solids may be fed to other livestock.

When removing solid wastes leave 1/2 to 1 inch of waste on the surface of earth lots to avoid disturbing the high organic compacted earth seal that develops at the soil surface. This surface seal coupled with the biological seal that develops under anaerobic conditions 14 - 18" below the surface, vertically eliminates downward movement of polluted water.

EFFLUENT COLLECTION AND STORAGE
(All Livestock Including Poultry)

WORKSHEET DESCRIPTION

Effluent liquids containing up to 4% solids and slurries containing 4 - 15% solids, result from confined animal (and poultry) feeding operations (CAFO's). Environmentally sound collection, transport, storage, and disposal of effluent (liquid waste) is essential to minimize ground water nitrate loading, odor, and flies. EFFLUENT IS A RESOURCE consisting of water, nutrients, and organic matter; all valuable commodities in Arizona.

E-1 <u>Effluent Collection Facilities</u>

a. Record total length of ditch or pipeline. If manifold, show layout with length and size on sketch. Control of effluent begins at the source.

b. Often times a concrete sump of tank is used to collect and store effluent for subsequent pumping to a higher or distant point. By knowing the sump dimensions and the difference between maximum and minimum water surface, the volume pumped per cycle is known. Pump information recorded can be used to obtain a Pump Characteristic Curve or table from the dealer or manufacturer, identifying the operation characteristics (head/capacity) of the pump in use.

c. By knowing the average time to pump the volume of water in b.1. through b.3. of the EFFLUENT COLLECTION WORKSHEET, a pumping rate can be calculated. Total pumping time per day times the rate will measure effluent discharge. Use a dial type electric clock or AC hour meter wired to the motor or switch side of the electrical circuit to record pumping time for a 7-10 day period; average to the nearest two hour period (0.1 day) for a daily effluent yield.

d. Identify how effluent presently moves from collection to storage.

E-2 <u>Effluent Storage Facilities</u>

a. To create an organic and/or biological seal at and below the soil surface, depth of effluent should be at least two feet. Thus pond liners i.e., compacted silty clay loam or clay loam blankets or impermeable membranes should be considered where storage facilities may dry between use cycles. Temporary effluent storage on feed lot surfaces are an exception.

b. This entry is intended to identify the principle type of bacteria involved in the digestion process. Aerobic bacteria use oxygen, while anaerobic bacterial activity id reduced in the presence of oxygen. A properly designed and operated aerobic lagoon is odorless. A properly designed and operated anaerobic lagoon will usually have some odor but not be objectionable most of the year. All lagoons (or ponds) are aerobic in the top 0 - 3 feet. Rapid change in effluent depth release the most odor.

E-2. continued ...

c. Some facilities have existing concrete storage tanks. Except for fluctuating water surfaces and very sandy soils large concrete storage tanks are usually not necessary. Arizona CAFO's are large, thus reducing tank storage time to just a few days. A large open concrete tank (less than 4' deep) may be a source of aerobic effluent for hydraulic floor and ally flush system water. With proper design, aerobic water can be pumped from a pond or lagoon surface.

d. The method of earth construction, date of construction, and size are indicative of structure stability. Size is used to calculate surface area for evaporation and precipitation; and volume for biological oxygen demand loading rate, and annual storage. Occasionally ponds and lagoons are not geometrical. Record size in narrative or show on sketch.

e. To complete the RMS, disposal of effluent must be considered. In Arizona, the three listed methods of disposal are the only accepted alternatives.

MEASURING
EFFLUENT DISCHARGE
FROM FACILITIES

WORKSHEET APPENDIX

a. Continuous Discharge

Continuous and steady effluent discharge rates may be measured :

1. In open channels or partially filled pipelines by :

   a. Modified Broadcrested Weir (Replogle) measuring flume or other appropriate flow measuring device.

   b. Five gallon bucket (or other known capacity container) and watch.

2. In full pipe flow by :

   a. Orifice Plates

   b. Venturi flow meters.

   c. Sonic flow meters.

b. Intermittent Discharge

Intermittent or cycle discharge measurements are a combination of volume and frequency; or flow rate, time, and frequency.

1. Measuring volume for intermittent discharge :

   a. Measure receiving sump length and width or diameter and multiply by the change in water surface (maximum minus minimum water surface elevation).

   b. If the sump is irregular in shape, average maximum and minimum water surface areas and multiply by the change in water surface evaluation.

2. Measuring frequency for intermittent discharge :

   a. Often the manager has an estimate of frequency i.e., how many cycles occur while cleaning, such as average two cycles every three hours, etc.

   b. Frequency may be calculated using total pump operation time per day divided by the time it takes to pump effluent each cycle.

3. Flow rate for each cycle can be measured in open channels or partially filled pipelines by :

   a. Modified Broadcrested Weir (Replogle) measuring flume or other appropriate flow measuring devices.

   b. Five gallon bucket (or other known capacity container) and watch.

   c. Portable flow measuring devices i.e., sparling flow meters, orifice plates, or current meter.

   d. If the discharge flow rate cannot be measured, a discharge estimate can be made using pump characteristic curves and Total Dynamic Head (TDH). Pump operational characteristics (or performance) is shown by curves or tables prepared by the manufacturer. Pump make, model number, kind or type, shaft rpm, and impeller diameter create a head/discharge relationship characteristic of only one pump. Thus be calculating TDH, including pump friction loss, pump/system discharge may be known. Request pump characteristic curves or tables from the pump dealer or manufacturer.

4. Pump time can be measured using a dial type electric clock or AC hour meter wired into the switch side of the pump motor electric circuit. When the pump motor runs, the clock runs. Measure operation for a 7 - 10 day period, the average for daily operation time. A QUALIFIED PERSON MUST MAKE ALL ELECTRIC CONNECTIONS.

5. A less accurate, but conservative, method to estimate effluent discharge from facilities is to estimate the volume of water pumped by the supply wells(s). Some CAFO facilities have a flow meter on the water supply.

   Knowing the supply pump kind, make, model number, number of impellers, impeller diameter may be estimated. Discharge rate times the hours per day pump operation gives a gross volume of water used. A dial type electric clock, AC hour meter, or in on a separate electric meter kilowatt hours may be used to estimate time of pump operation. Take measurements for 7 - 10 days to calculate a reasonable daily average.

   Using name plate pump discharge is not recommended. Water table elevation, plumbing to and from the pump, and impeller wear are variable affecting pump discharge.

   Deduct water lost by evaporation and non CAFO uses i.e., domestic use, landscape irrigation, etc. Deduct livestock drinking water if total manure (feces and urine) production is estimated.

Appendix C
Soil Data List

SOIL DATA LIST

The information on the Soil Data List is used in site selection for components of an agricultural waste management system. Most data items are used in the application of USDA (SCS) NRCS Technical Notes #716 and #717 for the design of waste management system components.

Name of Published Soil Survey

Soil Survey Map number ______________________________

Soil Map units ______________________________

Physical Characteristics
NOTE SOURCE: SS - Soil Survey, V - Site Visit, L - Lab test

1. texture ______________________________
2. organic matter (%) ______________________________
3. unified classification ______________________________
4. plasticity index ______________________________
5. liquid limit (%) ______________________________
6. permeability (inches/hour) ______________________________
7. bulk density ______________________________
8. depth to bedrock ______________________________
9. type of bedrock, presence of karst or fractured bedrock ______________________________

____

10. water table depth ______________________________
11. substrata permeability (inches/hour) ______________________________
12. hydrologic group ______________________________
13. flooding frequency ______________________________

CHEMICAL CHARACTERISTICS

1. cation exchange capacity (meq/100g) ______________________________ (ideally, greater than 15)

2. pH ____ (ideally, between 6.5 and 8.5)

3. Ec (mmhos/cm) ____ (ideally, less than 4)

GLOSSARY

Aerobic

Occurring in the presence of free oxygen.

Anaerobic

Conversion of organic matter in the absence of oxygen.

Agricultural/Animal Waste Management System (AWMS)

A combination of conservation practices and management that, when installed or applied, will protect the resource base.

(BOD) Biochemical Oxygen Demand

An indirect measure of the concentration of biodegradable substances present in an aqueous solution. Determined by the amount of dissolved oxygen required for the aerobic degradation to the organic matter at 20 degrees celsius. BOD_5 refers to that oxygen demand for the initial five days of the degradation process.

Bulk Density

A measurement of the mass of soil occupying a given volume. Expressed as $grams/cm^3$.

Cation Exchange Capacity

Ion exchange process in which cations (positively charged ions) in solution are exchanged for other cations from an ion exchanger. The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value.

Concentrated Animal Feeding Operation

Facility which confines, feeds and maintains more than 300 animal units for a total of 45 days or more in any 12 month period.

Denitrification

Anaerobic microbial reduction of oxidized nitrate nitrogen NO_3-N to nitrogen gas.

Detritus

Dead plant material that is in the process of microbial decomposition.

Effluent

Water, wastewater or other liquid leaving a facility or treatment unit.

Electrical conductivity

Conductivity of electricity through water or an extract of soil. Expressed in mmhos.

Emergent Plant

A rooted plant that grows in periodically or permanently flooded areas and has portions of the plant (stems and leaves) extending through and above the water line.

Evapotranspiration

The combined processes of evaporation from the water or soil surface and transpiration of water by plants.

Hydraulic Residence Time (HRT)

A measure of the average time that water occupies a given volume with units of time. Used to measure wastewater residence time in a constructed wetland for sufficient treatment.

Hydric Soil

A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions.

Influent

Water, wastewater or other liquid flowing into a waterbody or treatment unit.

Liquid Limit

The moisture content at which the soil passes from a plastic to a liquid state.

Nitrification

Biological transformation (oxidation) of ammonia nitrogen (NH_4-N) to nitrite (NO_2) and nitrate (NO_3) forms.

Oxidation

Chemical reaction in which the oxidation number (valence) of an element increases because of the loss of one or more electrons. Oxidation of an element is often accompanied by the addition of oxygen to the compound.

Permeability

The quality of the soil that enables water to move downward through the profile. Permeability is measured as the number of inches per hour that water moves downward through the saturated soil.

pH

The negative logarithm of the hydrogen ion concentration. The pH scale ranges from zero to 14. Values below 7 are considered acidic and those above, alkaline.

Plasticity Index

The numerical difference between the liquid limit and the plastic limit. The range of moisture content within which the soil remains plastic.

Plug Flow

Linear flow along the length of a wetland cell.

Salinity

A measure of the total salt content of water. Seawater is about 35 parts per thousand (ppt).

Sludge

Accumulated solids separated from liquids.

Submerged Plants

Aquatic plants that grow below the water surface for the majority of their lifecycles.

Substrate

Substances used by organisms for growth in a liquid medium. In constructed wetlands, refers to growth media for plants.

Transpiration

The transport of water vapor from the soil to the atmosphere through actively growing plants.

Unified Classification

System of soil classification according to properties that affect their use as construction material.

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E-1. continued ...

c. Average time sump pump runs per cycle is _______ minutes.

d. Existing effluent discharges via _______ ft open ditch, ______ ft of _______ inch dia. pipeline, _______ ft of _______ inch dia. pipeline and separating screen, wild flooding _______ , other ___________ .

E-2. <u>Effluent Storage Facilities</u> (Does not include sump and pump facilities in Section E-1.)

a. Storage facilities contain effluent: less than 30 days ______ , more than 30 day but less than 12 months _______ , year round _______ .

b. Normal depth of effluent storage is : 0 - 3 ft _______ , (aerobic), 3 - 5 ft. ______ (aerobic and mixed), more than 5 ft. _______ , (aerobic, mixed and anaerobic)

c. Dimensions of concrete storage tank(s) if used:

Length Feet	Width Feet	Diameter Feet	Depth Feet
_______	_______	_______	_______
_______	_______	_______	_______

d. Method of construction, age, and size of earth storage pond(s) or lagoon(s):
Method of construction: excavated _______ , excavated and embankment _______,
embankment _______ , embankment only _______ , Year of construction ______

Length Feet	Width Feet	Diameter Feet	Depth Feet
_______	_______	_______	_______
_______	_______	_______	_______

Date: ___________

EFFLUENT COLLECTION
AND STORAGE
(All Livestock Including Poultry)
Site Visit Worksheet

Effluent (liquid waste) from CAFO's includes: animal urine, facility wash water, processing water, feed lot and solid waste storage area runoff. This section applies to the collection and storage of effluent outside to buildings. Effluent may contain up to 4% solids.

E-1. Effluent Collection Facilities

a. Effluent exits buildings in _______ ft open ditch, _______ ft of _______ dia. pipeline. Is a manifold configuration used? Yes ____ , No ____ . If yes, use sketch to show layout, sizes and lengths.

b. Is a temporary storage sump and pump used? Yes _______ , No _______ . If no, proceed to section E-1 d.; if yes:

1. Sump dimensions are ___ ft length and ___ ft width, or ___ ft diameter. Sump is constructed of ________________ .

2. Minimum effluent surface is _______ feet below top of sump.

3. Maximum effluent surface is _______ feet below top of sump.

4. sump pump spec's: motor horsepower ________ , make ________ , model number _______ , shaft rpm ________ , impeller diameter _______. Effluent discharge elevation is ______ feet above the lowest effluent surface in the sump.

d. continued ...

Are ponds or lagoons lined or unlined? __________

If lined, what is material used for lining? _______________

Where available, identify subsurface details of structure:

Clay depth ____ Sand Depth ____ Gravel depth ____

e. Ultimate disposal of effluent is:

1. Retention on feed lot surface and evaporated _______ .

2. stored in a sealed holding pond that may be dry part of the year _______ , and:

   a. applied on irrigated cropland w/IWM _______ ,

   b. evaporated _______ ,

   c. applied to roads or corrals for dust control _______.

3. Stored in a sealed year round pond or lagoon containing at least 24" of effluent any given month of the year, and:

   a. applied on irrigated cropland w/IWM _______ ,

   b. evaporated _______ ,

   c. applied to roads or corrals for dust control _______.

f. Other, describe: ____

____

____