Wastewater Land Application Operators Study and Reference Manual

State of Idaho

Department of Environmental Quality

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May 2014

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Acknowledgments

This manual is a combination of guidance materials gathered from various technical resources, with input and expertise from the Idaho Department of Environmental Quality wastewater engineering and technical staff.

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Acronyms, Abbreviations, and Symbols

°C degrees Celsius

µg microgram

µm micrometer

ac acre

AWC available water-holding capacity

BMP best management practice

BOD biochemical oxygen demand

Ca calcium

cb centibars

CEC cation exchange capacity

cmol centimols

COD chemical oxygen demand

CU consumptive use

Cu copper

DEQ Idaho Department of Environmental Quality

DO dissolved oxygen

E_i irrigation efficiency

EPA United States Environmental Protection Agency

ESP exchangeable sodium percentage

ET evapotranspiration

Fe iron

ft foot

g gram

gal gallon

gpm gallons per minute

H hydrogen

HDPE high-density polyethylene

HIV human immunodeficiency virus

IBOL Idaho Board of Occupational Licensing

IDAPA Numbering designation for all administrative rules in Idaho promulgated in accordance with the Idaho Administrative Procedure Act

in. inch

IR irrigation requirement

IWR irrigation water requirement

K potassium

kg kilogram

L liter

lb pound

MAD maximum allowable depletion

meq milliequivalent

Mg magnesium

mg milligram

MG million gallon

mL milliliter

mm millimeter

MR mineralization rate

MRML most recent mature leaf

MU management unit

N nitrogen

Na sodium

NGS nongrowing season

NPDES National Pollutant Discharge Elimination System

NRCS Natural Resources Conservation Service

NTU neophelometric turbidity unit

NVDS	nonvolatile dissolved solid
NVSS	nonvolatile suspended solid
O&M	operations and maintenance (manual)
OSHA	Occupational Safety and Health Administration
P	phosphorus
PAN	plant-available nitrogen
PAPR	powered air-purifying respirators
PAW	plant-available water
P_{def}	precipitation deficit
Pe	effective precipitation
PO	plan of operations
PPE	personal protective equipment
ppm	parts per million
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	quality assurance project plan
RI	rapid infiltration
SAR	sodium adsorption ratio
SCBA	self-contained breathing apparatus
SU	soil monitoring unit
TDS	total dissolved solid
TKN	total Kjeldahl nitrogen
TSS	total suspended solid
USDA	United States Department of Agriculture
UV	ultraviolet
V	volt
VDS	volatile dissolved solid
VR	volatilization rate
VSS	volatile suspended solid
WWLA	wastewater land application
yr	year
Zn	zinc

 Needs-to-know criteria

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Introduction

The goal of a recycled water land application system is to provide a method of treatment that protects the following:

- Public health
- The environment
- Waters of the state, including surface water and ground water

Land application systems are recognized by the Idaho Department of Environmental Quality (DEQ) and United States Environmental Protection Agency (EPA) as beneficial reuse systems. Two benefits of using land application technology are (1) eliminating the need for recycled water discharge into a surface water body and (2) providing recycled water as the primary source of irrigation water for nutrient utilization by crops that are grown and harvested on land application sites. Furthermore, a properly sited and operated land application system offers exceptional treatment and renovation as well as a source of aquifer recharge in some instances.

However, as with any treatment process, mismanagement can result in negative consequences. Overapplication of recycled water to the land can result in runoff or leaching (downward movement of pollutants) and potential contamination of surface water and ground water. Nutrients, metals, pathogens, salts, and other elements may cause environmental problems or health concerns if not properly managed.

Purpose of This Manual

The purpose of this manual is to provide wastewater land application (WWLA) operators with the basic understanding needed to operate land application systems in an efficient and environmentally sound manner and to prepare for the WWLA certification exam. WWLA certification is required by rule for municipal operators and this manual will primarily consider municipal sites.

This symbol indicates *Need-to-Know Criteria* that all WWLA operators must focus on and which may appear in the WWLA certification exam. This manual is not intended to provide all required details for the complete evaluation and management of a land application system but can be used as a general reference. The facility permit and plan of operations (PO) should also be consulted to complete the evaluation and management of the land application system. Note that the operations and maintenance (O&M) manual is a subset of the PO, and in this manual, the O&M manual may be used interchangeably as a reference to the PO.

This Manual and the Law

This manual presents material consistent with the laws, rules, and technical guidance for Idaho's reuse program that existed at the time the manual was written. It is likely that these laws and technical guidance have changed, so it is important to stay up-to-date.

Although the organizations and government agencies involved in WWLA operator certification will try to inform individuals who own and operate these systems of any changes, as they occur, WWLA operators are responsible for ensuring that they are operating in compliance with current laws and rules.

For questions about land application systems, contact DEQ. For questions about becoming licensed or maintaining an existing license as either a wastewater treatment operator or as a WWLA operator, contact the Idaho Bureau of Occupational Licenses.

How This Manual Was Developed

A committee of experts in the recycled water, regulatory, soils, agronomy, engineering, and associated fields developed the training materials for this manual. The manual is based on a list of topics and issues—referred to as *Need-to-Know Criteria*—the committee determined each operator of a land application system must know how to perform at a minimum level of competency. The manual and associated training program explain and demonstrate each *Need-to-Know Criteria*, so after completing the training, the operator should have the knowledge and tools to effectively operate a land application system.

Updates to This Manual

This manual will be periodically updated to reflect changes in laws and technology. For example, interest in odor reduction and drift control from recycled water irrigation fields is increasing, thereby increasing the interest in using application equipment that distributes recycled water at or close to the ground surface. Distribution techniques, such as low-drop nozzles on center pivot equipment and drip irrigation systems, meet some of these needs, but this manual cannot cover every type of hardware that is used in the field.

The basics of recycled water distribution and site operation and management are presented in some detail, as these apply to all sites. Special and unique systems are briefly mentioned; operators of such systems are encouraged to obtain specific operation and maintenance information from the system manufacturer, designer, or installer.

1 Roles and Responsibilities of the Wastewater Land Application Operator

Need-to-Know Criteria
Municipal and industrial reuse permit
Rules

Generally a WWLA operator is licensed to understand a reuse site that land applies recycled water under the terms of a state-issued reuse permit. The WWLA operator should understand the following:

- Reuse permit
- Difference between a municipal and industrial reuse permit
- Daily activities relating to the permit, which include the following:
  - Monitoring and collecting data
  - Collecting data of known quality that reflect/demonstrate terms in the permit
  - Communicating permit terminology
- State of Idaho rules that are followed under the permit:
  - Wastewater Rules, IDAPA 58.01.16
  - Recycled Water Rules, IDAPA 58.01.17
  - Ground Water Quality Rule, IDAPA 58.01.11
  - Water Quality Standards, IDAPA 58.01.02
  - Rules of the Board of Drinking Water and Wastewater Professionals (Wastewater Operator Licensing Rules and Operator Requirements), IDAPA 24.05.01

1.1 Permits

Most wastewater comes from domestic or industrial sources, and three types of reuse permits can be issued: municipal, industrial, or combined. The permittee (permit holder) is the person or entity to whom the reuse permit is issued that is legally responsible for complying with the terms of the reuse permit. The permittee is often the system owner. The permittee can designate the WWLA operator to be responsible for system operation. The WWLA operator should understand the permit and know what type of recycled water is used on their site.

1.1.1 Municipal Reuse Permit

Municipal (or domestic) wastewater is collected from homes and business and treated in a wastewater treatment facility. Domestic wastewater comes primarily from residences, nonindustrial businesses, and institutional sources. Examples of domestic wastewater are restroom (sanitary fixtures/appliances), laundry, and kitchen waste. Domestic wastewater tends to be fairly uniform in composition. If the treatment facility land applies the treated water (recycled water), the facility land applies under the terms of a state-issued reuse permit. The wastewater characteristics of the recycled water determine which of the five classes of recycled water (Classes A–E) that the site is permitted for in the reuse permit. Appendix A contains example permits. One example of a municipal reuse permit would be a city that treats with an aerated lagoon followed by chlorine disinfection to Class C standards and then land applies its recycled water to nonfood crops such as alfalfa. Another example would be a city that uses tertiary treatment to treat and disinfect to Class A standards and then distributes the recycled water to parks, businesses, and homes through purple pipe for nonpotable irrigation.

1.1.2 Industrial Reuse Permit

Industrial wastewater is discharged from industrial facilities and some heavy commercial operations. Industrial wastewater characteristics change with changing production rates and schedules, and it is much more variable than domestic wastewater, possibly containing toxic substances, such as metals. Concerns with the land application of high strength industrial wastewater include generation of nuisance odors and overloading the site with constituents (waste elements) in the recycled water stream. These systems typically require additional pretreatment and/or special site management practices to provide good performance. Industrial reuse permits are issued based upon the site-specific characterization of the treated recycled water and the site-specific conditions. Industrial wastewater can be of significantly higher strength than domestic wastewater. An example of an industrial reuse permit would be a food processor with high strength wastewater (high total dissolved solids and nitrogen) where they treat with lagoons, clarification, and then filtration before land applying to small grain crops (i.e., wheat) or corn. The majority of industrial reuse permits in Idaho are related to food processing (e.g., potatoes, sugar beets, other vegetables, dairy products, and meat processors).

1.1.3 Combined Reuse Permit

An industrial site may treat its industrial and municipal wastewater streams differently and need a permit that handles both streams appropriately. If the site is mixing municipal and industrial wastewater before treatment, then the permit will need to be a municipal reuse permit; if it keeps the treated and land-applied streams separate, then the facility needs a combined reuse permit.

- Mix streams = one municipal reuse permit, which contains limits for the combined recycled water.
- Two separated streams = a combined reuse permit, which may contain separate limits for the municipal and industrial recycled water streams as well as limits and conditions that apply to both streams.

1.2 Rules

The “Recycled Water Rules” (IDAPA 58.01.17) establish the procedures and requirements for issuing and maintaining reuse permits, and it is under these rules that reuse permits are issued. Rules are further discussed in section 16. The site-specific reuse permit will provide information on other rules that must be considered in operating the reuse site.

2 Recycled Water Classes (A-E)

Need-to-Know Criteria
Wastewater effluent classifications and level of treatment required as defined in the "Recycled Water Rules" (IDAPA 58.01.17).

Generally, any structure or system designed or used for reuse of municipal or industrial wastewater per DEQ's "Recycled Water Rules" (IDAPA 58.01.17) must have a DEQ-issued reuse permit and follow the requirements of the classification of the recycled water. The rules define the various classes of municipal recycled water (Class A–E) and each reuse permit will specify the classification for that facility. Classification of the municipal recycled water determines the options for the use of the recycled water from that facility. For example, land application is one type of use. Partial descriptions of the five recycled water classes are given in Table 2-1, Table 2-2, and Table 2-3 (IDAPA 58.01.17).

To use the tables, find the recycled water classification listed horizontally across the top of each table and follow the appropriate column down to determine specific treatment, disinfection, additional requirements, and typical uses of each recycled water class. These tables should be used along with the narrative of each classification listed in the sections following the tables.

The tables provide a quick reference for information regarding each recycled water classification. These tables are not intended to cover in detail all aspects with regard to each classification. The WWLA operator should consult the facility permit, IDAPA 58.01.17, and the *Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater* (DEQ guidance) for details associated with each recycled water classification.

Table 2-1. Recycled water classification.

Classification		Class A	Class B	Class C	Class D	Class E
Oxidized		Yes	Yes	Yes	Yes	No
Clarified		Yes	Yes	No	No	No
Filtered		Yes	Yes	No	No	No
Disinfected		Yes	Yes	Yes	Yes	No
Total coliform (organisms/ 100 milliliters)	Median results for last x-days for which analysis have been completed	2.2 7-day median	2.2 7-day median	23 5-day median	230 3-day median	No limit
	Maximum in any sample	23	23	230	2,300	No limit
	Monitoring frequency	Daily, or as determined.	Daily or as determined.	Once weekly or as determined	Once monthly or as	—
Disinfection requirements contact time		Contact time of 450 mg-min/L with 90 min of modal time, or disinfection to 5-log inactivation of virus	Total chlorine not less than 1 mg/L after 30-min contact time at peak flow or comparable alternate process	—	—	—

Notes: milligram (mg); liter (L); minute (min)

Table 2-2. Class A and Class B additional requirements.

Classification		Class A	Class B
Turbidity (NTU)	24-hour - mean, not to exceed	Granular or cloth media - 2 Membrane filter - 0.2	Granular or cloth media - 5
	Maximum, in any sample	Granular or cloth media - 5 Membrane filter - 0.5	Granular or cloth media - 10
	Monitoring frequency	Continuous	Continuous
Maximum total nitrogen (mg/L)		Ground water recharge - 10 Residential irrigation and other nonrecharge uses – 30 Or As required based on an analysis of ground water impacts	May be required based on an analysis of ground water impacts
BOD_5 (mg/L) Monthly arithmetic mean, from weekly composite samples not to exceed		Ground water recharge - 5 Residential irrigation and other nonrecharge uses - 10	—
pH Daily grab samples or continuous monitoring		Between 6.0 and 9.0	—

Notes: neophelometric turbidity unit (NTU); milligram per liter (mg/L); biochemical oxygen demand (BOD)

Table 2-3. Recycled water uses.

Recycled Water Uses	Class A	Class B	Class C	Class D	Class E
Uses Relating to Irrigation and Buffers					
Buffers required	No	Yes	Yes	Yes	Yes
Fodder, fiber crops	Yes	Yes	Yes	Yes	Yes
Commercial timber, firewood	Yes	Yes	Yes	Yes	Yes
Processed food crops or “food crops that must undergo commercial pathogen-destroying processing before being consumed by humans”	Yes	Yes	Yes	Yes	No
Ornamental nursery stock, or Christmas trees	Yes	Yes	Yes	Yes	No
Sod and seed crops not intended for human ingestion	Yes	Yes	Yes	Yes	No
Pasture for animals not producing milk for human consumption	Yes	Yes	Yes	Yes	No
Pasture for animals producing milk for human consumption	Yes	Yes	Yes	No	No
Orchards and vineyards irrigation during the fruiting season, if no fruit harvested for raw use comes in contact with the irrigation water or ground, or will only contact the inedible portion of raw food crops	Yes	Yes	Yes	No	No
Highway medians and roadside vegetation irrigation on sides	Yes	Yes	Yes	No	No
Cemetery irrigation	Yes	Yes	Yes	No	No
Parks, playgrounds, and school yards during periods of nonuse	Yes	Yes	No	No	No
Parks, playgrounds, and school yards during periods of use	Yes	No	No	No	No
Golf courses	Yes	Yes	No	No	No
Food crops, including all edible food crops	Yes	Yes	No	No	No
Residential landscape	Yes	No	No	No	No
Uses at Industrial, Commercial, or Construction Sites					
Dust suppression at construction sites and control on roads and streets	Yes	Yes	Yes	No	No
Toilet flushing at industrial and commercial sites, when only trained maintenance personnel have access to plumbing for repairs	Yes	Yes	Yes	No	No
Nonstructural fire fighting	Yes	Yes	Yes	No	No
Cleaning roads, sidewalks, and outdoor work areas	Yes	Yes	Yes	No	No
Backfill consolidation around nonpotable piping	Yes	Yes	Yes	No	No
Soil compaction	Yes	Yes	Yes	No	No

Commercial campus irrigation	Yes	Yes	No	No	No
Fire suppression	Yes	Yes	No	No	No
Snowmaking for winter parks, resorts	Yes	No	No	No	No
Commercial laundries	Yes	No	No	No	No
Ground Water Recharge					
Ground water recharge through surface spreading, seepage ponds, or other unlined surface water features, such as landscape impoundments	Yes	No	No	No	No
Subsurface Distribution					
Subsurface distribution	Yes	Yes	Yes	Yes	No

The WWLA operator is responsible for understanding the "Rules of the Board of Drinking Water and Wastewater Professionals" (IDAPA 24.05.01) and the certification that they need for the classification of the system. DEQ is responsible for determining system classifications and for ensuring that all wastewater systems that generate, collect, treat, or dispose of 2,500 or more gallons of wastewater per day are supervised by an appropriately licensed *responsible charge operator* and licensed operating personnel. Permittees are responsible for reporting to DEQ on the current classification status every 5 years. It is also the permittee's responsibility to ensure that the responsible charge operator and substitute responsible charge operator have the appropriate level of licensing that is equal to or greater than the system's classification. Therefore, Class B through E recycled water systems must have a certified operator. Class A systems at the treatment plant prior to distribution will need wastewater operators that are certified. No certified operator is needed on the distribution system of a Class A system. However, the operator of a Class A distribution system must sign a utility user agreement provided by the Class A recycled water utility stating that the distribution system operator understands the origin of the recycled water and the appropriate requirements for the Class A distribution and reuse system.

2.1 Class A Recycled Water

The WWLA operator should understand the general difference between Class A and other classes. If the WWLA operator is working with Class A recycled water, the details of the permit and the requirements in IDAPA 58.01.17 should be understood.

Class A recycled water receives the most treatment of all the classes and is of the highest quality and therefore can be used for applications where human contact is likely, such as distribution to homeowners for irrigation of yards and landscape or recharging potable aquifers. The treatment process typically includes secondary treatment followed by filtration to extremely low turbidity standards prior to disinfection. Class A disinfection processes must meet strict requirements to ensure pathogen destruction. Class A systems also require additional reliability and redundancy measures and increased monitoring to ensure treatment and effluent quality. The tables above discuss special requirements for treatment, chlorine disinfection, turbidity, water parameters, and uses. In general Class A recycled water has more uses than other classes with less restriction and in some cases no restriction at all (such as no buffer zones). This section reviews other requirements found in IDAPA 58.01.17.

- For disinfection, Class A recycled water can be disinfected using chlorine, ozone, ultraviolet (UV) radiation, and other alternative methods. When other methods for chlorine disinfection are used, the permit will define the requirements. It is recommended that Class A recycled water also is disinfected following storage.
- Sampling and analysis of Class A recycled water are defined in the permit. Generally there are daily requirements for disinfection sampling. For example, the effluent must be sampled and analyzed daily for total coliform during periods of application.
- Turbidity requirements shall be met prior to disinfection, and continuous in-line monitoring shall occur as described in IDAPA 58.01.17.
  - For filtration systems using sand or other granular media or cloth media, the daily arithmetic mean of all measurements of turbidity shall not exceed 2 neophelometric turbidity units (NTU), and turbidity shall not exceed 5 NTU at any time.
  - For filtration systems using membrane filtration, the daily arithmetic mean of all measurements of turbidity shall not exceed 0.2 NTU, and turbidity shall not exceed 0.5 NTU at any time.
- Nitrogen, pH, and 5-day biochemical oxygen demand (BOD_5) requirements
  - Total nitrogen at the point of compliance shall not exceed 10 milligrams per liter (mg/L) for ground water recharge systems and 30 mg/L for residential irrigation and other non-recharge uses.
  - The pH as determined by daily grab samples or continuous monitoring shall be between 6.0 and 9.0.
  - BOD_5 shall not exceed 5 mg/L for ground water recharge systems, and 10 mg/L for residential irrigation and other non-recharge systems, based on a monthly arithmetic mean as determined from weekly composite sampling.
- Reliability and redundancy requirements are required for monitoring, equipment (i.e., pumps), and treatment trains and are specified in IDAPA 58.01.17 and the “Wastewater Rules” (IDAPA 58.01.16). Standby power sufficient to maintain all treatment and distribution works shall be required for the Class A systems as described in the rules.
- Class A effluent identification is required, and all new buried pipe, including service lines, valves, and other appurtenances, shall be colored purple (Pantone 512) or equivalent. If fading or discoloration of the purple pipe is experienced during construction, identification tape or locating wire along the pipe is required. Label piping every 10 feet with “Caution: Recycled Water - Do Not Drink” or equivalent signage in both Spanish and English. If identification tape is installed along with the purple pipe, it shall be prepared with white or black printing on a purple field, Pantone 512, or equivalent, with the words, “Caution: Recycled Water - Do Not Drink” or equivalent signage in both Spanish and English. The overall width of the tape shall be at least 3 inches. Identification tape shall be installed 18 inches above the transmission pipe longitudinally, shall be centered over the pipe, and shall run continuously along the length of the pipe.
  - Existing water lines that are being converted to use with Class A effluent shall first be accurately located and comply with leak test standards in accordance with the American Water Works Association Standards and in coordination with DEQ. The

pipeline must be physically disconnected from any potable water lines and brought into compliance with current state cross-connection rules and requirements in accordance with "Idaho Rules for Public Drinking Water Systems" (IDAPA 58.01.08.543), and must meet minimum separation requirements (IDAPA 58.01.08.542.07). If the existing lines meet approval of the water supplier and DEQ based upon the requirements set forth in IDAPA 58.01.17.607.02.b, the lines shall be approved for Class A effluent distribution. If regulatory compliance of the system (accurate location and verification of no cross connections) cannot be verified with record drawings, televising, or otherwise, the lines shall be uncovered, inspected, and identified prior to use. All accessible portions of the system must be retrofitted to meet the requirements of these rules. After conversion of the water or irrigation line to a recycled water effluent line, the lines shall be marked as stated in IDAPA 58.01.17.607.02.b.

- All valve covers shall be of non-interchangeable shape with locking potable water covers and shall have an inscription cast on the top surface stating "Recycled Water." Valve boxes shall meet the requirements of IDAPA 58.01.17.603.01a.iii. All aboveground pipes and pumps shall be consistently color-coded purple (Pantone 512) and marked to differentiate Class A effluent facilities from potable water facilities.
- All exposed and aboveground piping, risers, fittings, pumps, and valves shall be color-coded purple (Pantone 512) or equivalent. In addition, all piping shall be identified using an accepted means of labeling, reading "Caution: Recycled Water - Do Not Drink" or equivalent signage in both Spanish and English. In a fenced pump station area, signs shall be posted on the fence on all sides.
- Warning labels shall be installed on designated facilities such as, but not limited to, controller panels and wash-down or blow-off hydrants on water trucks, hose bibs, and temporary construction services. The labels shall read, "Caution: Recycled Water - Do Not Drink" or equivalent signage in both Spanish and English.
- Where class A recycled water is stored or impounded, or used for irrigation in public areas, warning signs shall be installed and contain, at a minimum, 1-inch purple letters (Pantone 512 or equivalent) on a white or other high contrast background notifying the public that the water is unsafe to drink. Signs may also have a purple background with white or other high contrast lettering. Warning signs and labels shall read, "Caution: Recycled Water - Do Not Drink" or equivalent signage in both Spanish and English.

2.2 Class B Recycled Water

The WWLA operator should understand the general difference between Class B and other classes. If the WWLA operator is working with Class B recycled water, the details of the permit and requirements in IDAPA 58.01.17 should be understood.

Class B recycled water is the second most treated of all the classes and the second highest in quality. It requires treatment similar to Class A systems. The notable differences are reduced turbidity requirements following filtration and less extreme disinfection requirements. Class B has many uses, but it cannot be distributed to homeowners for residential irrigation or used for ground water recharge. It can be used to irrigate all types of crops, including edible food crops.

Class B systems have reduced reliability and redundancy requirements in comparison to Class A systems. Table 2-1, Table 2-2, and Table 2-3 discuss special requirements for treatment, chlorine disinfection, turbidity, water parameters, and uses. Operator requirements for the treatment and distribution system are required. This section reviews other requirements found in IDAPA 58.01.17.

- For disinfection, Class B recycled water can be disinfected using chlorine, ozone, UV radiation, and other alternative methods. When other methods for disinfection are used, the permit will define the requirements. It is recommended that Class B recycled water also be disinfected following storage.
- Sampling and analysis of Class B recycled water are defined in the permit. Generally there are daily requirements for disinfection sampling. The point of compliance for Class B recycled water for total coliform shall be at any point in the system following final treatment and disinfection contact time. For example, the effluent must be sampled and analyzed daily for total coliform during periods of application. The sampling frequency for Class B and Class A is similar.
- Turbidity requirements shall be met prior to disinfection and continuous in-line monitoring shall occur as described in IDAPA 58.01.17.
  - The daily arithmetic mean of all the measurements of turbidity shall not exceed 5 NTU and shall not exceed 10 NTU at any time.
  - The turbidity shall be met prior to disinfection.
- Periods of use—Class B recycled water shall be applied only during periods of nonuse by the public.

2.3 Class C Recycled Water

The WWLA operator should understand the general difference between Class C and other classes. If the WWLA operator is working with Class C recycled water, the details of the permit, requirements in IDAPA 58.01.017, and site-specific issues relating to health and safety should be understood.

Class C recycled water systems are generally secondary treatment (oxidation) and disinfection. Filtration is not a requirement of Class C systems. Disinfection requirements are less stringent than Class A and B, and as a result the allowable uses are reduced. For example, it can be used to irrigate fodder crops, processed food crops (food crops that undergo commercial pathogen destroying processes), and some types of orchards. Class C is the most common type of municipal reuse system in Idaho. Table 2-1, Table 2-2, and Table 2-3 discuss special requirements for treatment, chlorine disinfection, and uses. Operator requirements for the treatment and distribution system are required. This section reviews other requirements found in IDAPA 58.01.17.

- For disinfection, Class C recycled water can be disinfected using chlorine, ozone, UV radiation, and other alternative methods. When other methods for disinfection are used, the permit will define the requirements. It is recommended that Class C recycled water is disinfected following storage.
- Sampling and analysis of Class C recycled water are defined in the permit. Generally there are weekly requirements for disinfection sampling. The point of compliance for

Class C recycled water for total coliform shall be at any point in the system following final treatment and disinfection contact time. For example, the effluent must be sampled and analyzed weekly for total coliform during periods of application.

2.4 Class D Recycled Water

The WWLA operator should understand the general difference between Class D and other classes. If the WWLA operator is working with Class D recycled water, the details of the permit, requirements in IDAPA 58.01.17, and site-specific issues relating to health and safely should be understood.

Class D recycled water is similar to Class C as it requires oxidation and disinfection. The primary difference in treatment between Class C and Class D is the disinfection requirements are an order of magnitude lower for Class D recycled water. As a result, the allowable uses are more limited than Class C. Irrigation of fodder, processed food crops, and forests are allowed uses of Class D recycled water. Table 2-1, Table 2-2, and Table 2-3 discuss special requirements for treatment, chlorine disinfection, and uses. Operator requirements for the treatment and distribution system are required. This section reviews other requirements found in IDAPA 58.01.17.

- For disinfection, Class D recycled water is disinfected to a lower level than the other classes by using chlorine, or another alternative method. When other methods for disinfection are used, the permit will define the requirements.
- Sampling and analysis of Class D recycled water are defined in the permit. Generally there are monthly requirements for disinfection sampling. The point of compliance for Class D recycled water for total coliform shall be at any point in the system following final treatment and disinfection contact time. For example, the effluent must be sampled and analyzed monthly for total coliform during periods of application.

2.5 Class E Recycled Water

The WWLA operator should understand the general difference between Class E and other classes. If the WWLA operator is working with Class E recycled water, the details of the permit, requirements in IDAPA 58.01.17, and site-specific issues relating to health and safety should be understood.

Class E recycled water requires primary treatment only (no disinfection). Allowable uses of Class E are very limited due to the high potential pathogen content remaining in the recycled water. Table 2-1, Table 2-2, and Table 2-3 discuss special requirements. Operator requirements for the treatment and distribution system are required. This section reviews other requirements found in IDAPA 58.01.17.

- For disinfection, there are no disinfection requirements or applicable coliform standards for Class E recycled water.
- Sampling and analysis of Class E recycled water are not generally required unless there are buffer zone issues that are defined in the permit.

- Public access is restricted with Class E recycled water, and animals shall not be pastured or grazed on land where Class E municipal wastewater is applied.

2.6 Industrial Recycled Water

The WWLA operator should understand the general difference between the classes of municipal recycled water and that industrial recycled water is not classified. If the WWLA operator is working with industrial recycled water, the details of the permit, requirements in IDAPA 58.01.17, and site-specific issues relating to use, health, and safety should be understood. The permit requirements are determined on a case-by-case basis and developed for each industrial site.

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3 Reuse Permit Template

Need-to-Know Criteria
Facility information
Compliance activities and compliance schedules
Reuse permit limits and conditions
Reuse permit monitoring requirements
Reporting requirements
Standard permit conditions
General permit conditions
Site maps

The WWLA operator must understand the site’s reuse permit. Appendix A contains generic examples of reuse permits. The generic examples reflect the differences between municipal and industrial permits. Some of the differences between municipal and industrial permits include the following:

Municipal Permits

- Technical, financial, and managerial requirements
- Operator certification requirements
- Approved backflow assemblies or an air gap are required between potable water supplies and all nonpotable water supplies
- Divided into recycled water classes
- Specific infrastructure requirements depending on the class of recycled water
- Require lagoon seepage testing every 10 years

Industrial Permits

- Do not have technical, financial, and managerial requirements
- Generally do not have operator certification requirements
- Do not require approved backflow assemblies but typically require backflow devices
- Are not divided into recycled water classes
- Require lagoon seepage testing on a case-by-case basis based on site-specific issues and water characteristics.
- May contain limits and conditions to address the specific characteristics of the industrial recycled water

3.1 Facility Information

The facility information has the permit type, recycled water class, and treatment method. The WWLA operator should understand the facility information. The WWLA operator should ensure that the facility information in the permit is correct, notify the permittee if it is not correct, and inform the permittee to update the permit details with DEQ. Only DEQ is authorized to make changes to the reuse permit requirements. The permittee is responsible for complying with all permit conditions and may be held liable for violation of permit conditions.

3.2 Compliance Activities and Compliance Schedules

The compliance activities and schedules are facility specific requirements of the permit and must be completed as stated in the permit. The WWLA operator should understand the compliance activities and schedules in the permit and keep the permittee informed as necessary. Failure to comply with the requirements could result in the facility being subject to enforcement action. Examples of a compliance activity would be the PO, solids management, runoff management, and lagoon seepage testing plans. Such plans are required to be submitted by specific dates and require DEQ approval prior to implementation. The quality assurance project plan (QAPP) is also an example of a compliance activity that is self-implementing and required to be in place by a certain date; it is reviewed by DEQ for content, but this plan is not approved by DEQ.

3.3 Reuse Permit Limits and Conditions

All permit limits and conditions must be followed.

3.3.1 Management Unit Descriptions

A management unit (MU) is a portion of the land application site that is permitted to receive recycled water. The amount of recycled water each MU receives is referred to in the permit as the hydraulic-loading rate. Each land application site typically consists of more than one MU. The WWLA operator must be familiar with each of the permitted MUs and the associated limits and conditions. Each MU may have different loading rates and management practices (e.g., unique irrigation and cropping practices).

Each MU has associated monitoring serial numbers—MU-XYZ-##: management unit serial number.

Other typical monitoring point serial numbers are as follows:

- SU-XYZ-##: soil monitoring unit serial number
- WW-XYZ-##: wastewater monitoring serial number
- SW-XYZ-##: supplemental irrigation water monitoring serial number
- GW-XYZ-##: ground water monitoring serial number
- LG-XYZ-##: lagoon monitoring serial number
- FM-XYZ-##: flow measurement monitoring serial number

The associated reuse permit number designation is XYZ, and the ## is a two-digit designation for each monitoring point.

3.3.2 Hydraulic-Loading Limits

The WWLA operator will need to manage MUs based upon growing season and nongrowing season hydraulic-loading limits of the permit for each MU.

3.3.3 Constituent-Loading Limits

The WWLA operator will also need to manage MUs based upon the constituent loading so that permit limits are met and adverse impacts to soil and ground water are minimized. The recycled water constituents determine the loading that can be applied to each MU, and most often the limiting constituent is nitrogen. Constituents are further discussed in section 3.4.1.

3.3.4 Management Unit Buffer Zones

The WWLA operator will also need to manage the site for compliance with buffer zone requirements. Deficiencies should be reported to the permittee for correction. The site-specific details are in the permit and in the "Recycled Water Rules" (IDAPA 58.01.17).

3.3.5 Other Permit Limits and Conditions

The WWLA operator will also need to read the permit to learn about other limits and conditions applied to the site, including operator certification requirements, growing and nongrowing season time frames, reporting time frames for the annual report, coliform limits (applicable to municipal systems), crop or vegetation allowed, grazing (grazing requires a management plan, preapproved by DEQ), fencing, posting, and construction plan and specification requirements.

3.4 Reuse Permit Monitoring Requirements

In support of the agency's mission, DEQ is dedicated to using and providing objective, correct, reliable, and understandable information. Decisions made by DEQ are subject to public review and may, at times, be subject to rigorous scrutiny. It is, therefore, DEQ's goal to ensure that all decisions are based on data of known and acceptable quality. Monitoring points are specified in the reuse permit, and monitoring must be done according to the permit. To ensure that data and results will be of the appropriate quality, the QAPP should be referenced when taking any samples. The QAPP should be used in conjunction with the site's PO. WWLA operators taking monitoring samples should ensure that a QAPP has been developed for all monitoring and sampling and that the QAPP is followed. WWLA operators may contact the DEQ regional office for compliance assistance with monitoring and sampling.

Note
Failure to carry out any or all of these activities or comply with the terms and conditions of the permit is a violation of Idaho law and may subject the permittee to enforcement action and/or a civil penalty assessment.

3.4.1 Constituent Monitoring

Constituent monitoring is required in both municipal and industrial permits, and each permit will be unique for the site-specific issues. Table 3-1 is provided below to show how constituent monitoring requirements are listed in each permit. Each monitoring point sample location along with the associated serial number is listed in the first column. A detailed sample description is shown in column two with the sample type and frequency shown in column three. The actual constituents to be sampled at each monitoring point are listed in column four. For example, Table 3-1 shows recycled water from lagoon ABC at the pump no. 1 sampling port with serial number WW-0XY-01, which samples recycled water to MU-0XY-01, 02, and 03. A grab sample is taken monthly during periods of recycled water use for total Kjeldahl nitrogen (TKN), nitrate + nitrite nitrogen, total phosphorus, nonvolatile dissolved solids, and chloride, and a grab sample is taken weekly for MU-0XY-02 and monthly for MU-0XY-03 for total coliform. A similar table is included in each permit issued by DEQ. This table is an example; each permit will be unique.

Table 3-1. Constituent monitoring.

Monitoring Point Serial Number and Location	Sample Description	Sample Type and Frequency	Constituents (Units in milligrams per liter unless otherwise specified)
WW-0XY-01 Recycled water from lagoon ABC at pump no. 1 sample port	Recycled water to MU-XYZ-01, MU-XYZ-02, and MU-XYZ-03	Grab/monthly (during periods of use)	- Total Kjeldahl nitrogen, as N - Nitrite + nitrate-nitrogen, as N - Total phosphorus, as P - Nonvolatile dissolved solids - Chloride
	Recycled water to MU-0XY-02	Grab/weekly (during periods of use)	- Total coliform (total coliform organisms/100 milliliters)
	Recycled water to MU-0XY-03	Grab/monthly (during periods of use)	
WW-0XY-02 Low strength process pond from pump no. 2 sample port	Recycled water to MU-XYZ-04	Grab/monthly (during periods of use)	- Ammonia nitrogen, as N - Nitrite + nitrate-nitrogen, as N - Total phosphorus, as P
SW-0XY-01 ABC Canal	Supplemental irrigation water	Grab sample (May and September of the first and third permit year)	- Nitrite + nitrate-nitrogen, as N - Total phosphorus, as P - Nonvolatile dissolved solids

3.4.2 Management Unit and Other Flow Monitoring

To meet the permit requirements, the WWLA operator will need to accurately monitor recycled water flows to the reuse site. The WWLA operator may also be responsible for monitoring wastewater flows to various components in the treatment plant. Flow monitoring data are needed to properly manage the reuse site and determine site constituent-loading rates to each MU and are typically required as part of the annual report. Flow calibration requirements should be addressed as outlined in the plan of operation review or QAPP. The site PO (section 4) should outline typical maintenance requirements and frequencies for each flow monitoring device.

3.4.3 Ground Water Monitoring

The reuse permit may specify ground water monitoring, and the WWLA operator may be responsible for ground water monitoring if it is required in the permit. Ground water monitoring provides data that can be used to evaluate a facility's impact on ground water as well as evaluate ground water quality changes with respect to changes in hydraulic loading and site management.

The site QAPP should outline the ground water sampling procedures for each monitoring well. The WWLA operator should also be familiar with well construction enough to understand or recognize any construction deficiencies or well component degradation that may result in ground water contamination or impact ground water quality (Appendix B). For example, improper seal, damaged casing, or improper berming. The WWLA operator should clearly communicate to the permittee and responsible agencies the well names, locations, and conditions along with monitoring needs as specified in the reuse permit. The WWLA operator should also understand which wells are upgradient and downgradient from the application site.

3.4.4 Soil Monitoring

The WWLA operator may be responsible for soil sampling at each MU as designated by the soil monitoring unit (SU) in the permit. The site QAPP should outline the soil sampling for each SU. Section 6 of this manual further discusses soil. The WWLA operator should know the boundaries of each SU (typically the same boundaries as the MU) and understand any variations between each SU in the permit.

3.4.5 Plant Tissue Monitoring

Plant tissues reflect the health and nutrient uptake of the crop. The WWLA operator may be responsible for taking samples and ensuring that crop yields and tissue samples are recorded. Section 6.7 of this manual further discusses agronomy and nutrient uptake.

3.4.6 Lagoon Information

Lagoons are often a unit process in wastewater treatment or provide storage for recycled water. Seepage testing of each lagoon is often a permit requirement or required by rule. Seepage testing requirements are specified in new permits. Older permits may not include the requirements and DEQ should be consulted if there are questions regarding testing. Section 9 of this manual further discusses lagoons, lagoon construction, and seepage testing. The WWLA operator should also be familiar with lagoon construction requirements to recognize any construction deficiencies or lagoon component degradation that may result in increased lagoon seepage or any life and safety issues regarding the integrity of the lagoon embankments.

3.5 Reporting Requirements

The reuse permit will define the reporting requirements. All data collected need to be submitted to DEQ in the annual report; however, the minimum reporting is specified in the reuse permit. At minimum, records must be retained for the length of permit plus 2 years.

3.5.1 Annual Reports Requirements

The annual report is a narrative summary that discusses data collected during the year and documents the facility’s permit compliance to DEQ. The annual report shall be prepared by a competent environmental professional who is familiar with the permitted facility and can use the monitoring data to describe the site conditions as they apply to the land application treatment of the recycled water.

The WWLA operator should know what data are being monitored and collected for the annual report based upon the permit. The WWLA operator should also know and understand why the data are being monitored and collected to help understand, evaluate, and operate the system to maintain compliance. The annual report is a permit requirement with due dates and required content that is submitted to DEQ in written form. The permit outlines the information that should be submitted in the site-specific annual report. Appendix C provides recommendations of details to include in the annual report.

Yearly, the facility must submit an annual report, prepared by a competent environmental professional, no later than January 31 of each year (unless otherwise specified in the reuse permit), covering the previous reporting year, typically November 1 through October 31. The annual report includes results of required monitoring, the status of any compliance activities specified in the permit, and an interpretive discussion of monitoring data and public complaints, with particular respect to environmental impacts by the facility. All laboratory reports containing the sample results for required monitoring and other site-specific data are also submitted with the annual report.

Annual report submittals shall include a certification statement, which is signed, dated, and certified by the permittee’s responsible official or an authorized person representing the responsible official. Refer to your reuse permit for the certification statement language and the responsibilities it requires.

3.5.2 Emergency and Noncompliance Reporting

The WWLA operator needs to know the reporting requirements of the permit and communicate them to the permittee. The permittee is required to report all noncompliance incidents to the applicable DEQ regional office according to the standard permit conditions, which state that all noncompliance events must be reported orally to DEQ within 24 hours and in writing within 5 days with an action plan for correcting the violation. For emergencies, the WWLA operator is required to call the 24-hour emergency number and the appropriate DEQ regional office.

All instances of unpermitted wastewater discharges to surface waters of the United States shall also be reported to EPA by telephone within 24 hours from the time the permittee becomes aware of the discharge and in writing within 5 days to the following address:

National Pollutant Discharge Elimination System/
Stormwater Coordinator, EPA Idaho Operations Office
950 W. Bannock, Suite 900
Boise, ID 83702
(208) 378-5746 or (208) 378-5744 and EPA Hotline: (206) 553-1846

3.6 Permit for Use of Industrial Water

Permit for use of industrial water contains the requirements specific to industrial facilities. This section will be marked reserved on municipal permits.

3.7 Standard Permit Conditions

Standard conditions are specified in every reuse permit. The permittee is responsible for complying with the permit, and the WWLA operator is expected to know and follow these conditions. An important condition is how and when emergencies and noncompliance issues are dealt with and reported by the facility to DEQ.

3.8 General Permit Conditions

General permit conditions cover those DEQ rules that apply to the permit at the time the permit was issued. These conditions cover operations and administrative rules that the WWLA operator needs to know.

3.8.1 Operations

These conditions cover the rules associated with facility operations, including backflow prevention, preventing runoff of recycled water, health hazards, nuisances, and odor prohibitions, solids management, temporary cessation of operations and closure, PO, seepage testing requirements (will be marked as reserved for industrial permits), and ground water quality. The WWLA operator is expected to know and follow these conditions.

3.8.2 Administrative

These conditions cover the rules associated with the administrative portion of the facility, including permit modifications, permit transfer, permit revocation, violations, and severability. The WWLA operator should know and follow these conditions.

3.9 Other Applicable Laws

Other applicable laws or rules that are not enforced by DEQ may be applicable. For example, the Idaho Department of Water Resources has rules that are applicable to all ground water wells located at the reuse facility. These rules include well use, maintenance, repair, and abandonment.

3.10 Site Maps

Site maps are a part of each permit and help the WWLA operator and others unfamiliar with the site orient themselves with critical elements of the site. Site maps also help the WWLA operator in locating potential problems and explaining to DEQ and others where possible noncompliance problems exist on site, and allow off-site personnel the needed information to solve problems in a timely manner. These maps include regional and facility maps.

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4 Permit Required Documents—Plans

Need-to-Know Criteria
Plan of operations
Quality assurance project plan

4.1 Plan of Operations

A PO, which includes the O&M manual and various permit-required facility plans, functions as a site-specific guide for day-to-day operations of a land application site. A facility's PO must contain all system components relating to the reuse facility in order to comply with IDAPA 58.01.16. The reuse permit and PO should be used together in the day-to-day operations of the reuse facility to direct the operation, maintenance, and reporting activities at the land application site. The O&M manual portion of the PO contains the physical components and operations at the facility and must meet the requirements of IDAPA 58.01.17.300.05, and the specific contents of the Reuse Permit. The permit required facility plans portion of the PO contains the administrative and sampling requirements for the nonphysical operations conducted at the facility. The associated sampling requirements are further controlled by a facility QAPP. The WWLA operator should be familiar with the QAPP so that permit required sampling is reliable and reproducible. The reuse permit will require a QAPP and associated facility plans.

Figure 4-1 shows the relationship between the PO, O&M manual, various facility plans, and QAPP.

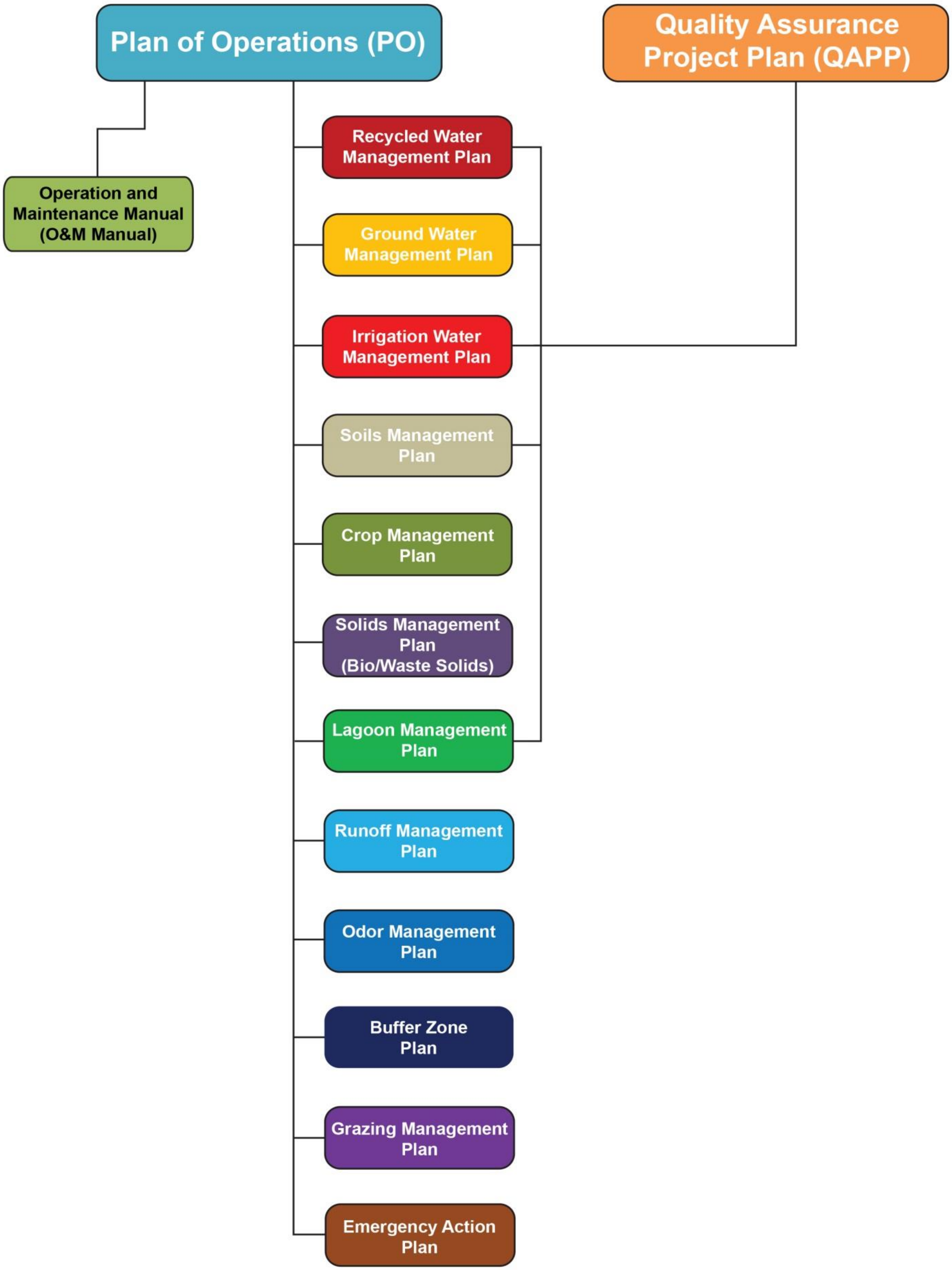

Figure 4-1. Relationship between the PO, O&M manual, various facility plans, and QAPP.

A *PO checklist* in DEQ guidance lists the minimum information that shall be incorporated into the document. A partial list of items in the PO checklist is given below.

- Organizational chart and operator and manager responsibilities.
- Copy of the reuse permit and a list applicable rules, statutes, and standards.
- Facility maps.
- General plant description—Treatment design criteria, wastewater characterization, and list of unit operations.
- O&M manual—Each facility shall maintain an O&M manual contained within the PO specific to that facility. The O&M manual shall be developed and used as an operator guide for actual day-to-day operations to meet requirements of the facility's reuse permit.
- Description, operation, and control of unit operations—Description of process, major components and mechanical equipment, discussion of common operating problems and start-up procedures, and equipment operating instructions with reference to equipment O&M manual.
- Wastewater and recycled water storage lagoons—Description and purpose, capacity, operating instructions, and seepage rate testing requirements.
- Reuse site features, buffer zone delineations, fencing and postings, backflow prevention, climatic characteristics, soils, topography, surface water, ground water, description of irrigation systems and operating instructions, and determination of hydraulic- and constituent-loading rates.
- Vegetation—Describe crops or vegetation that will be used on each reuse site.
- Management plans for buffer zones, grazing, controlling nuisance conditions, waste solids, runoff/run-on, and others as required by the reuse permit.
- Monitoring activities and requirements.
- Maintenance—Preventative maintenance schedule, troubleshooting guides, and manufacturer's manuals.
- Records and reports—Daily operating log, maintenance records, laboratory records, and reports, and reporting permit violations and accidents.
- Personnel—Staffing requirements and qualifications.
- Emergency operating plan—Emergency numbers and emergency procedures.

All system components should have specification sheets, showing details of the units as well as operation and maintenance requirements. These are usually included in the O&M manual or attached as a supplement. If this information is not present, the WWLA operator should contact the manufacturers directly.

Typically, equipment will have a specification plate with the company name, location, and component model or serial number. Manufacturer information on servicing the equipment should be found in the O&M manual. If the manufacturer is no longer in business, a local repair service may be able to provide service or information. If no information is available, service units similar to other units with like components.

Specific management plans, in addition to information provided in the facility O&M manual, may be required per the facility reuse permit. Some example plans and important aspects of each are presented below.

- Grazing management plan—DEQ guidance specifies under what circumstances livestock grazing on land application sites is allowed. Prior to any grazing activities, a grazing management plan must be submitted to DEQ for review and approval. Items typically addressed in a grazing management plan include specifying the type and number of animals to be grazed, identifying the schedule for rotating animals through the site, preparing a nutrient balance, identifying the disinfection level of the applied recycled water, and identifying the minimum waiting periods prior to grazing animals on sites irrigated with recycled water.
- Odor management plan—An odor management plan addresses all wastewater treatment systems, land application facilities, and other operations associated with the facility. The plan includes specific design considerations, operation and maintenance procedures, and management practices to be employed to minimize the potential for or limit odors. The plan also includes procedures to respond to an odor incident, if one occurs, including notification procedures.
- Waste solids management plan—This plan describes how waste solids generated at the facility, including dredgings and sludges, are handled and disposed of in a manner specific to the rules the different wastes may need to follow. The reuse permit will discuss the differences between the waste solids and rules that may apply. The waste solids management plan prevents waste entry, or the entry of contaminated drainage or leachate into the waters of the state, so that health hazards and nuisance conditions are not created, and impacts to designated beneficial uses of the ground water and surface water are prevented.
- Emergency action plans—Emergency action plans cover various situations that may occur such as transportation spills, site runoff, power outages, major equipment failure, and bomb threats. (A detailed discussion of emergency action plans is presented in section 13.6.1).

4.2 Quality Assurance Project Plan

A QAPP is a written document outlining the procedures that the reuse sites use to ensure the data it collects and analyzes meet permit requirements.

Quality data and information constitute the foundation of informed decision making, and a QAPP ensures that the data collected by monitoring projects are of known and suitable quality and quantity. The QAPP summarizes the data quality objectives of the project and integrates all technical and quality aspects—including planning, implementation, and assessment—into a single document. For example procedures used for collecting and evaluating different monitoring parameters should be included in the QAPP. The WWLA operator should consult the QAPP every time they are sampling.

In support of the agency mission, DEQ is dedicated to using and providing objective, correct, reliable, and understandable information. Decisions made by DEQ are subject to public review and may, at times, be subject to rigorous scrutiny. It is, therefore, DEQ's goal to ensure that all decisions are based on data of known and acceptable quality. A QAPP must be submitted to DEQ as a stand-alone document for review and acceptance to assist in planning for the collection, analysis, and reporting of all monitoring data in support of the reuse permit and in explaining data anomalies when they occur. DEQ does not approve QAPPs but reviews them to determine if the minimum EPA guideline requirements are met and that the reuse facility permit requirements are satisfied. The reason DEQ does not approve QAPPs is that the responsibility for validation of the facility sampling data lies with the permit holder and DEQ's responsibility is not to validate this information as an on-site quality assurance officer.

The format of the QAPP should adhere to the recommendations and references in the Quality Assurance and Data Processing sections of the DEQ guidance. QAPPs developed using the DEQ guidance should also agree in substance with EPA's QAPPs. Copies of the associated EPA guidance documents and example QAPPs can be downloaded or printed from the following website: *http://www.epa.gov/quality/qapps.html.*

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5 Reporting and Monitoring Wastewater and Recycled Water Constituents/Parameters

Need-to-Know Criteria
Total, suspended, and dissolved solids
Pathogens
Total coliform bacteria (parameter used as an indicator of potential pathogen levels)
Nitrogen cycle
Hydraulic-loading rate; growing season versus nongrowing season
Constituent-loading rates; nitrogen, phosphorus, and chemical oxygen demand
Land-limiting constituent

The WWLA operator must know what wastewater monitoring is required and the wastewater characteristics and loading to appropriately manage the reuse site. The reuse permit will provide information on the parameters that are managed at the land application site. To properly operate and maintain a WWLA system, it is necessary to understand the basic characteristics of wastewater. Although domestic wastewater is predominately composed of water, certain constituents contained in wastewater are important factors in the design, operation, and management of reuse land application systems.

5.1 Wastewater

Wastewater contains two primary types of waste: *organic* and *inorganic*.

- Organic wastes originate from plant or animal sources and can generally be consumed by bacteria and other organisms. All organic wastes contain carbon.
- Inorganic wastes come from mineral materials, such as sand, salt, iron, calcium, and these wastes are only slightly affected by biological activity.

The source of wastewater influences the amount of organic and inorganic waste in a particular wastestream. For example, wastewater from a meat processing plant will contain high levels of organic waste, while wastewater from a gravel washing operation will contain high levels of inorganic waste.

5.2 Wastewater Physical Characteristics

Physical characteristics of wastewater include color, odor, temperature, and the levels of solids present. Changes in these physical characteristics can indicate unusual *influent* (wastewater entering a treatment system) or operating conditions that may influence other factors such as biological activity.

5.2.1 Color

Raw municipal wastewater (prior to any treatment) is usually gray in color. Pretreated wastewater will have a color that indicates the pretreatment system; wastewater treated in a septic tank will have a gray-black color, but wastewater that has been treated in an aerobic process will have little color. The color of wastewater can also be affected by industrial contributions to the treatment system; color contributed by industry typically is not removed by the pretreatment system. Operators should be aware of such colors depending upon the type of facility being managed. Changes to the water coloration typical of the facility may need investigation.

5.2.2 Odor

Raw municipal wastewater usually produces a musty odor, generally caused by the anaerobic decomposition of organic material. Hydrogen sulfide is frequently the source of a rotten-egg odor in wastewater and can be a public health concern at relatively low concentrations. Other volatile sulfur-containing compounds, such as *mercaptans*, can also cause noxious odors. These odors are released into the air when wastewater is aerated and sometimes when the wastewater is discharged to a land application site. As a point of reference, mercaptans are added to natural gas to impart a detectable odor for leak detection and safety purposes.

Other or unexpected odors, such as petroleum or solvent odors, may indicate abnormal industrial discharges. Operators should be aware of such odors depending upon the type of facility being managed. Changes to the odors typical of the facility may need investigation.

5.2.3 Temperature

Wastewater is generally somewhat warmer than tap water. Noticeable increases or decreases in wastewater temperature may indicate influence from other sources such as industrial discharge, stormwater, or ground water infiltration.

Temperature is an important factor in *microbial* activity. Up to a point, an increase in wastewater temperature will increase microbial activity. However, when wastewater reaches high temperatures, microbial activity will be inhibited.

During land application of recycled water, high water temperatures can also adversely impact crops. Operators should be aware of temperature variations depending upon the type of facility being managed. Changes to the temperatures typical of the facility may need investigation.

5.2.4 Solids

One of the primary functions of a wastewater treatment system is the removal of solids. Solids can reduce the effectiveness of wastewater disinfection systems and clog land application equipment.

Determining the forms and concentrations of solids present in wastewater provides useful information for the control of treatment processes. Solids are divided into several different fractions, as shown in Figure 5-1. The individual fractions are determined through specific laboratory analysis.

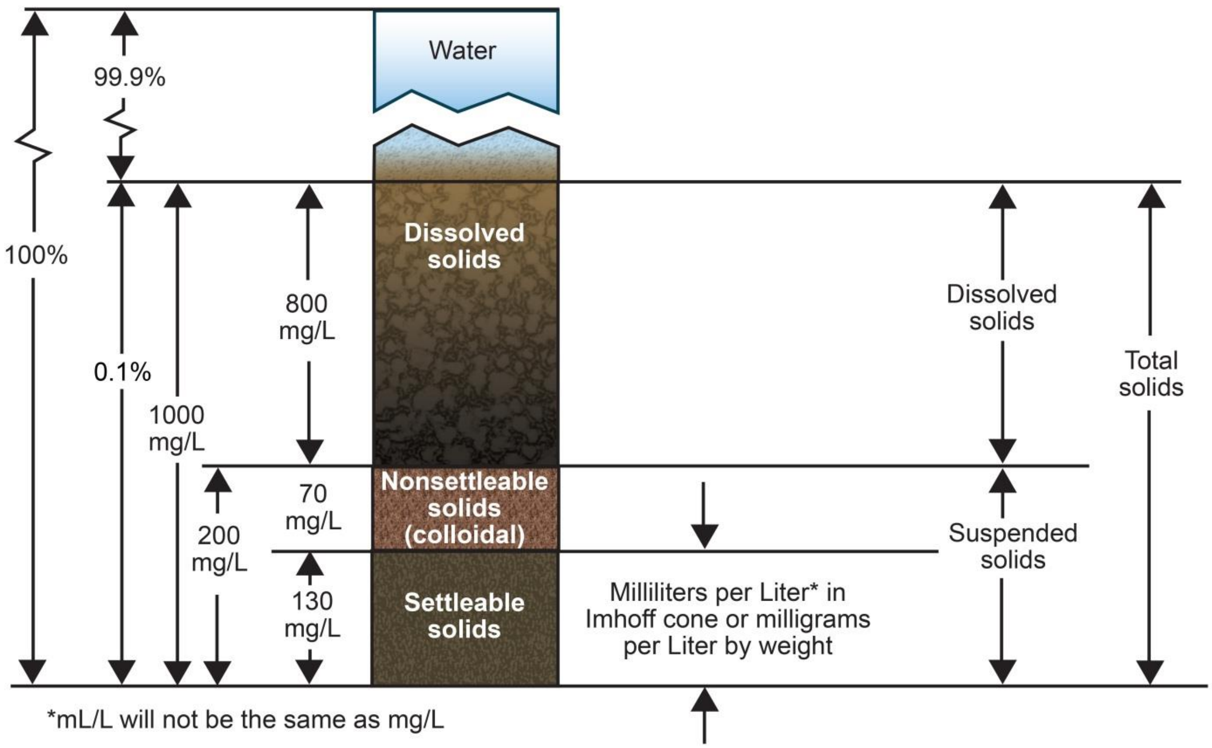

Figure 5-1. Typical composition of solids in raw municipal wastewater (modified from EPA 2004).

5.2.4.1 Total Solids (Residue)

Total solids are the amount of material that remains after the wastewater is evaporated at a temperature of 103 °C to 105 °C (Figure 5-2). Figure 5-1 represents an example of a 1-liter sample of typical municipal wastewater containing 1,000 mg of total solids. The proportion of different solids is a function of the wastewater source. It is not representative of all wastewater streams. It is expected that industrial wastewater proportions will be different than municipal wastewaters. Operators should be aware that wastewater compositions will vary depending upon the type of facility being managed.

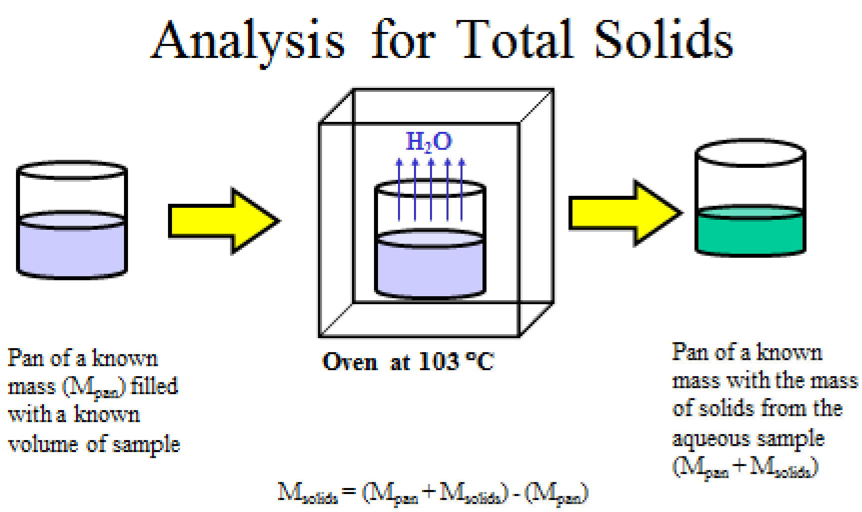

Figure 5-2. Analysis for total solids (Butler 2003).

5.2.4.2 Dissolved Solids

Dissolved solids or total dissolved solids (TDS), also called *filterable residue*, are those solids that will pass through a filter with a nominal pore size of 2.0 micrometers (µm). TDS include both organic and inorganic fractions.

- Total dissolved inorganic solids are the inorganic fraction of the TDS.
- Volatile dissolved solids (VDS) are the solids that can be volatilized and burned off when TDS are ignited (500 ± 50 ºC).
- Nonvolatile dissolved solids (NVDS) are the difference between TDS and VDS (NVDS = TDS – VDS).

Removal of dissolved inorganic solids from wastewater is difficult to achieve in standard municipal wastewater treatment systems, so concerns with land-applying wastewaters that have high concentrations of dissolved solids include (1) the potential for increased levels of dissolved solids in ground water and (2) the potential for adversely affecting soil properties that are important to land application operations. Industrial effluent typically contains more dissolved solids than municipal wastewater. In reuse permits, dissolved solids are further defined into the categories described in the following sections.

5.2.4.3 Suspended Solids

Suspended solids, or total suspended solids (TSS) also called *nonfilterable residue*, are the portion of total solids retained by filtration (Figure 5-3).

Volatile suspended solids (VSS) are the solids that can be volatilized and burned off when TSS are ignited at 500 ± 50 ºC (Figure 5-4).

Nonvolatile suspended solids (NVSS) are the difference between TSS and VSS (NVSS = TSS – VSS).

Suspended solids can be removed from a wastewater stream by physical, biological, and/or chemical processes. These solids are classified as either *settleable* or *nonsettleable* (*colloidal*), depending upon their size, shape, and density (weight per unit volume). Heavier, more dense particles tend to settle more rapidly than lighter, less dense particles.

Raw wastewater settleable solids concentration is an important factor for the design of settling basins, sludge pumps, and sludge-handling facilities. Measuring the amount of settleable solids entering the treatment unit allows calculation of the solids removal efficiency of the treatment unit. Settleable solids are typically measured using an Imhoff cone. An Imhoff cone is a clear, cone-shaped container marked with graduations. The cone is used to measure the volume of settleable solids in a specific volume (usually 1 liter) of water or wastewater.

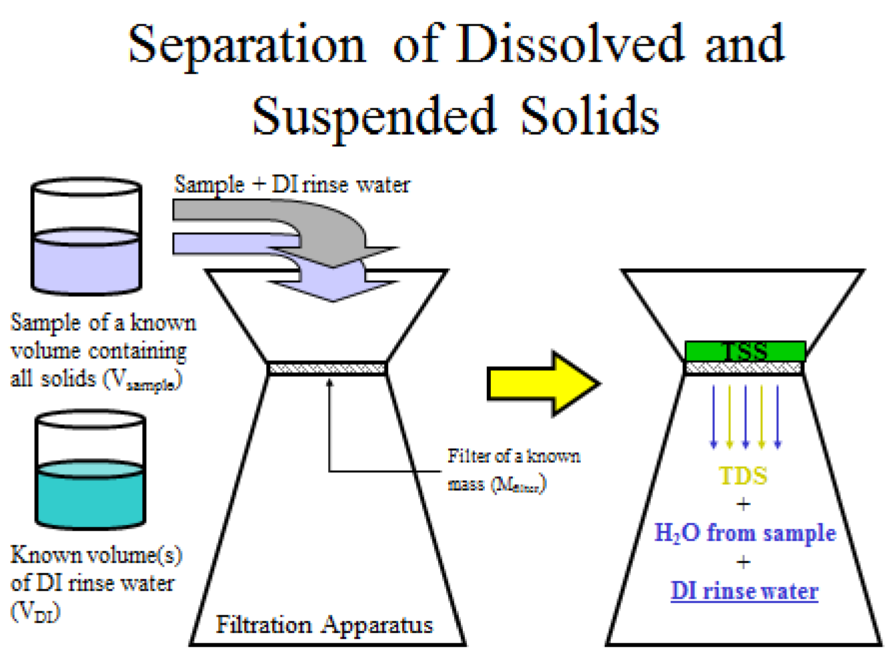

Figure 5-3. Separation of dissolved and suspended solids (Butler 2003).

Equation 5-1 can be used to calculate the weight of nonsettleable solids.

Weight of nonsettleable Solids	=	Weight of Total Solids	-	Weight of Dissolved Solids	-	Weight of Settleable Solids

Equation 5-1. Calculation for weight of nonsettleable solids.

In Figure 5-1, the nonsettleable solids concentration is shown as 70 mg/L.

Concerns with the land application of recycled waters with high concentrations of suspended solids include (1) the potential for reducing the infiltration capacity of the soil (clogging the soil), (2) the potential for damaging the crop and (3) the potential for premature or frequent clogging of irrigation filters and irrigation equipment (especially dragon filters and sprinkler nozzles).

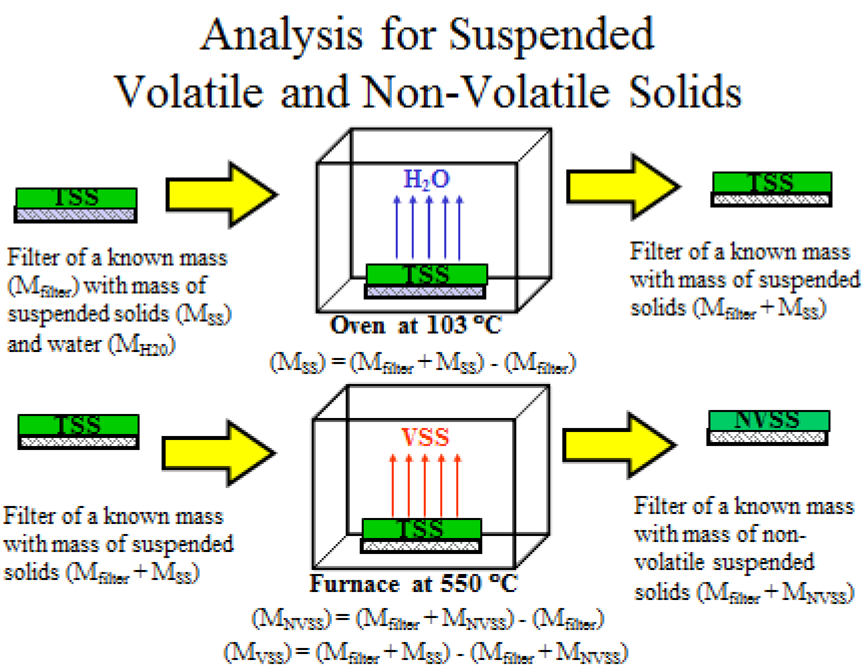

Figure 5-4. Analysis for suspended volatile and nonvolatile solids (Butler 2003).

5.3 Other Important Wastewater Characteristics

Other wastewater characteristics important to land application site management include pathogenic organisms, *biochemical oxygen demand* (BOD), *chemical oxygen demand* (COD), *dissolved oxygen* (DO), nutrients, metals, persistent organic chemicals, pH, and salts.

5.3.1 Pathogenic Organisms

The WWLA operator should know what pathogens are and how they are regulated in the permit. DEQ uses an indicator (the number of total coliform bacteria) for determining the potential for a sample to have pathogenic organisms present. Operators need to understand that total coliform bacteria levels are an indication that pathogens may be present. The classes of municipal recycled water are based on turbidity and total coliform bacteria.

Raw domestic wastewater contains many billions of microorganisms per gallon. Most of these are not harmful to humans, and some of them are helpful in wastewater treatment processes.

Disease-causing microorganisms are called *pathogens*, and they include bacteria, viruses, fungi, helminths, and protozoa. Pathogens cause disease in other organisms, however, not all pathogens are disease causing in humans. Examples of diseases that may be spread through wastewater discharges to humans are typhoid, cholera, shigellosis, dysentery, polio, and hepatitis. Pathogens can lead to disease; however, for a pathogen to cause disease, it must have a susceptible host, a pathway of exposure, and there must be an infective dose. Without these three elements, disease cannot occur. Wastewater treatment, reuse methods, and management practices are used to address one or more of these elements.

Many pathogenic organisms are killed during the normal treatment processes; however, sufficient numbers can remain in the *effluent* (treated wastewater leaving the treatment system) to cause a threat to any downstream use involving human contact if adequate disinfection is not accomplished in the treatment process.

5.3.1.1 Identification of Pathogens

It is impractical to test wastewater for all pathogens. Instead, indicator bacteria are commonly used to identify the possible presence of pathogens.

Some bacteria commonly used as indicators are *total coliform bacteria*, *fecal coliform,* or *Escherichia coli*. Total coliform bacteria are always present in the digestive systems of humans and warm-blooded animals. If there is a large concentration of coliform bacteria present in wastewater, the potential for the presence of pathogens is high. Total coliform bacteria are typically reduced in number during normal wastewater treatment processes. Total coliform bacteria are used as the primary indicator of potential pathogens in municipal recycled water in Idaho. The reuse permit may specify total coliform or another organism as the pathogen potential indicator.

5.3.1.2 Removal of Pathogens

Wastewater treatment processes remove pathogenic organisms in several ways: physical removal through filtration and sedimentation, natural die-off of organisms because of unfavorable environments, and destruction of organisms by disinfection. Disinfection processes further reduce pathogen levels of the recycled water and the requirement for municipal recycled water is based upon the recycled water class. (Disinfection is discussed in more detail in section 8).

5.3.2 Biochemical Oxygen Demand and Chemical Oxygen Demand

The WWLA operator should know what biochemical and chemical oxygen demand are and understand the loading limit of the parameter on the reuse site.

BOD measures the rate that microorganisms use oxygen to stabilize or break down (oxidize) the organic matter in wastewater biologically.

- High levels of BOD indicate high levels of organic matter in wastewater. The typical range of BOD in municipal wastewater ranges from 100 to 300 mg/L of BOD.

- BOD is measured using a biochemical oxygen demand test, a procedure that measures the amount of oxygen used by a wastewater sample incubated at 20 °C for 5 days. The amount of organic material measured is referred to as BOD_5, referring to the 5-day length of the test.

COD measures the amount of organic matter that can be broken down (oxidized) chemically.

- COD can estimate the amount of organic matter in wastewater in only 3 to 4 hours, rather than the 5 days required for the BOD_5 test and can be used as an alternative.

- The COD test measures the *oxygen equivalent* (in milligrams per liter) of the materials present in the wastewater by oxidizing the wastewater using a strong chemical oxidant. Because the chemical oxidant may react with substances that cannot be broken down by bacteria, COD results are not directly related to BOD_5. However, COD can be used as a means of rapidly estimating the BOD_5 of a sample if BOD_5-to-COD ratios are developed for a particular system. COD results are typically higher than the BOD_5 value when enough oxygen is present because *chemicals* (COD) are *stronger* and can break down (oxidize) organic matter more quickly than biological organisms (BOD). The ratio between the two will vary from system to system. The BOD_5-to-COD ratio is typically 0.6:1 for raw domestic wastewater and may drop to as low as 0.1:1 for a well-stabilized secondary effluent.

5.3.3 Dissolved Oxygen

DO is the amount of oxygen dissolved in water and is usually expressed in milligrams per liter. Although some microorganisms can survive in *anaerobic* conditions (without oxygen), many of the beneficial microorganisms that stabilize wastewater require *aerobic* conditions (with oxygen).

The amount of oxygen that can be dissolved in water depends on temperature—as water temperature increases, DO content decreases and vice versa—and the distribution of oxygen within a lagoon (or pond) will determine whether the treatment processes involved are aerobic or anaerobic. Maintaining adequate oxygen levels allows the biological process to take place and prevents objectionable odors. Low DO concentrations (less than 1.0 mg/L) can indicate inadequate aeration or an excessive amount of organic material entering the system.

DO is measured using an oxygen meter equipped with a membrane-covered probe. Probes require careful cleaning, and meters must be calibrated routinely to ensure accuracy.

5.3.4 Nutrients

A *nutrient* is any substance that promotes growth and can be taken up by plants or other organisms. Wastewater generally contains nutrients, such as nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulfur. In a land application system, recycled water can provide essential nutrients to crops. If present at excessive levels, however, some nutrients can become pollutants.

The WWLA operator should know what nutrients need to be managed on the reuse site and understand the loading rate limitations.

5.3.4.1 Nitrogen

All life-forms require nitrogen compounds, such as proteins and nucleic acids, to survive. The largest source of nitrogen is the air we breathe—approximately 78% of air is nitrogen gas (N_2), but most organisms cannot use nitrogen in this form. Most plants receive their nitrogen in a *fixed* form (i.e., nitrate ions [NO_3^-], ammonia [NH_3], and urea [$2(NH_2)CO$]), and animals receive their nitrogen from plants. There is a class of plants called legumes that use nitrogen from the air to meet nutritional requirements. Alfalfa, one of the most common crops at reuse sites, is a legume.

The nitrogen cycle (Figure 5-5) describes the reactions that nitrogen may undergo. Nitrogen starts as a gas (N_2) in the atmosphere and is transformed into other forms of nitrogen through nitrogen fixation. Nitrogen is fixed naturally through atmospheric fixation (by lightning) or through biological fixation (by certain microbes living alone in the soil or in a symbiotic relationship with plants in the legume family, such as soybeans and alfalfa, or nonlegume plants such as alders). Nitrogen is also fixed industrially in the production of fertilizers, which consist of ammonia, urea, and ammonium nitrate (NH_4NO_3). As plants and animals die, organic forms of nitrogen are returned to the environment, where microorganisms convert the organic nitrogen to ammonium. Much of the ammonia and ammonium produced by decay and manures are further broken down by nitrifying bacteria into nitrite ions (NO_2-) and then into nitrate ions (NO_3-), which are available to plants. The nitrogen cycle is completed when denitrifying bacteria convert nitrate ions back into atmospheric nitrogen.

Nitrogen in wastewater occurs in four different forms: organic nitrogen, ammonia (NH_3) or ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). In raw wastewater, organic nitrogen and ammonia levels are generally higher than nitrite and nitrate levels. Proteins, polypeptides, nucleic acids and urea, and numerous synthetic organic materials in wastewater contribute to the organic nitrogen. The nitrogen cycle reactions are important because nitrogen is a potentially serious pollutant in wastewater, and its behavior in and benefits to a wastewater land application system are highly dependent on which form the nitrogen is in when applied to the site.

In the nitrate form, nitrogen becomes a highly mobile anion. In this highly mobile form, when the soil nitrogen concentration exceeds permit limits, nitrates can be beneficial or cause adverse impacts depending on how the land application site is loaded. If the soil nitrogen concentration exceeds the permit limits for crop uptake, the excess nitrates will be carried below the root zone where it may adversely affect ground water quality. Therefore, the site must be operated to avoid exceeding the permit nitrogen limits.

Total nitrogen is the sum of organic nitrogen, ammonia, nitrite, and nitrate. TKN is the sum of organic nitrogen and ammonia. Typical ranges of nitrogen concentrations in raw domestic wastewater are 20 to 85 mg/L for total nitrogen, 8 to 35 mg/L for organic nitrogen, and 12 to 50 mg/L for ammonia. Plant-available nitrogen (PAN) is nitrogen that exists in forms (NH_4^+ and NO_3^-) that are readily available for uptake by plants.

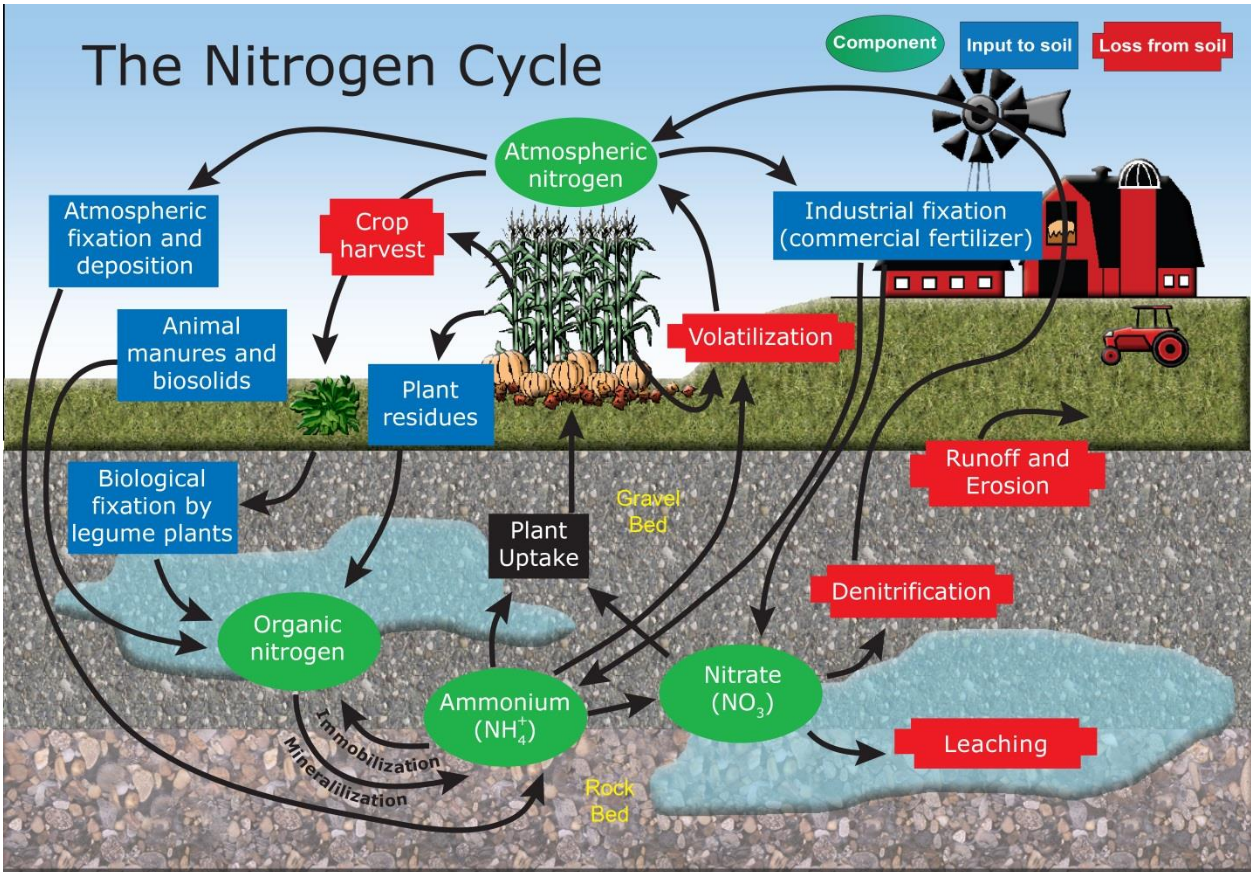

Figure 5-5. The nitrogen cycle.

5.3.4.2 Phosphorus

Phosphorus, like nitrogen, occurs in several forms in wastewater and is an essential element for biological growth and reproduction (Figure 5-6). Phosphorus can be present as orthophosphate, polyphosphate, and organic phosphate. These forms are often measured in combination, as *total phosphate* (total phosphorus). In domestic wastewater, total phosphorus levels generally range from 2 to 20 mg/L, including 1 to 15 mg/L of organic phosphorus and 1 to 15 mg/L of inorganic phosphorus.

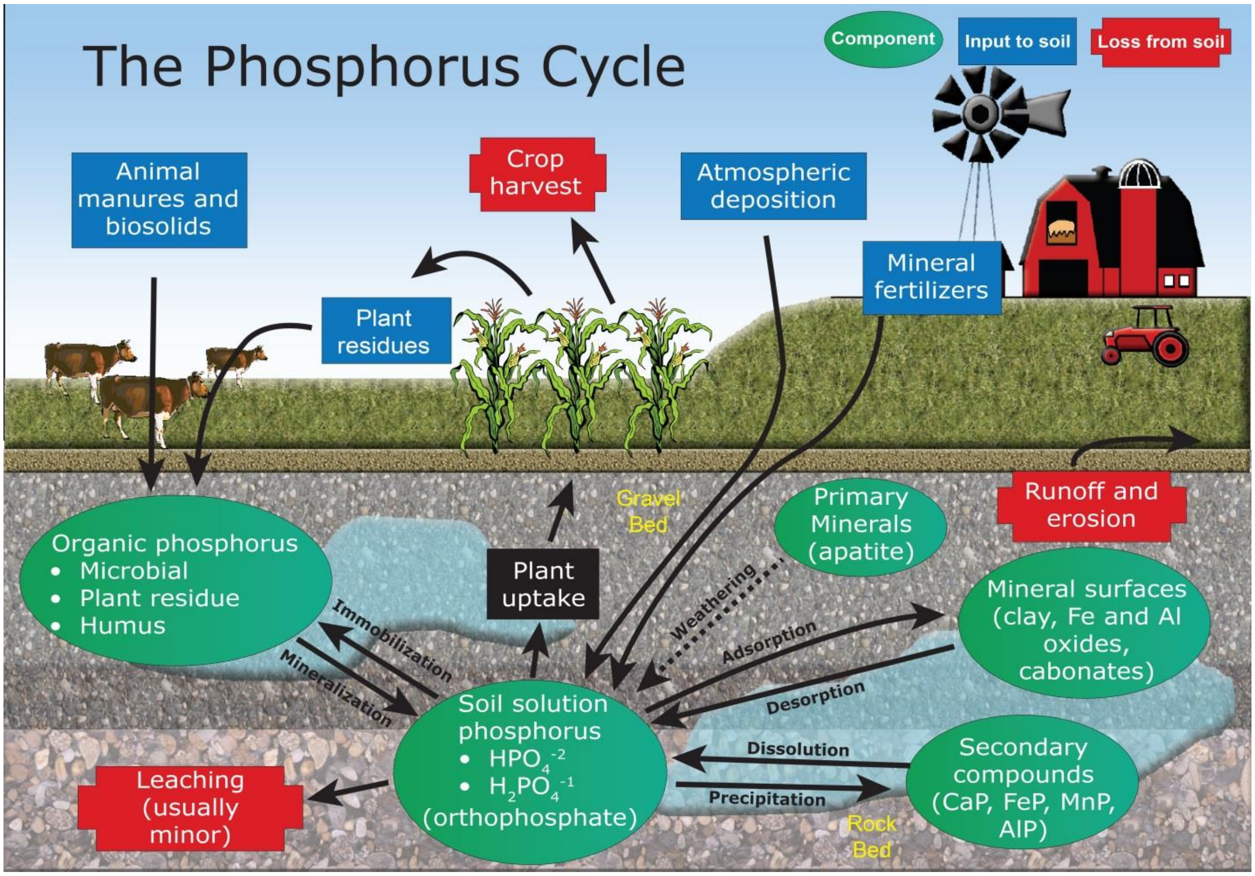

Figure 5-6. The phosphorus cycle.

5.3.5 Metals

Metals are inorganic chemical elements that are present in varying amounts in most wastestreams. Although some metals are essential for proper human and plant nutrition, over time they can accumulate in soils and become toxic to plants, humans, and other animals.

Metals of concern include cadmium, copper, lead, nickel, zinc, selenium, arsenic, mercury, and molybdenum. Cadmium, arsenic, chromium, and mercury are extremely toxic; nickel, molybdenum, and lead are moderately toxic; and copper, manganese, and zinc are relatively low in toxicity.

Concentrations of metals will vary with the type of wastewater. A typical domestic wastewater has low concentrations of metals, but an industrial wastewater may be very high in metal concentration.

The primary concern with using soil to assimilate heavy metals is that these metals are stable and often resist weathering and decomposition. Although plants generally resist the uptake of metals from the soil, their accumulation on plant leaves through irrigation may permit them to enter various food chains, where they become part of the life cycle of soil, plants, animals, and humans, accumulating in animal and human body tissue to toxic levels. This situation is especially critical for humans, who reside at the end of the food chain.

Because of the potential health effects of metals, it is necessary to properly manage land application sites to minimize the effects of metals on human health and the environment. The permit will specify monitoring for metals and the site is to be managed so that there is enough land to minimize accumulation. The life expectancy of the site may be based upon the accumulation of metals or other toxic substances.

5.3.6 Persistent Organic Chemicals

Although microorganisms can readily decompose most organic wastes, some organic chemicals are not readily biodegradable and can persist in water and soil for many years. These *persistent organic chemicals* can reach the soil in many ways. They are sometimes a component of pesticides (insecticides and herbicides), or they may be found in the wastestream that is being treated at the land application site. Persistent organic chemicals are also found where old underground storage tanks have leaked petroleum products into the soil.

With a municipal or domestic waste source, persistent organic chemical concentrations are likely to be extremely low, or nonexistent. These chemicals may be present in higher concentrations, however, in an industrial waste source. Like metals, persistent organic chemicals can be toxic to animals and humans.

5.3.7 pH

pH is the measure of the concentration of the hydrogen ions (H^+) in a solution. A pH of 7 is neutral, while a pH reading below 7 indicates *acidic* conditions and a pH reading above 7 indicates *alkaline* (*basic)* conditions. The pH of domestic wastewater typically ranges from 6.5 to 7.5, depending on the pH of potable water in the service system. Significant departures from these values may indicate industrial or other nondomestic discharges.

In land application systems, bacteria may perform wastewater treatment in pretreatment units and in the soil. These bacteria prefer a neutral pH (or 7) for best performance. Any rapid increase or decrease in pH can cause mortality in the bacteria population, resulting in poor treatment.

Note
Acidity is the capacity of water to neutralize bases. Water does not have to be strongly acidic (low pH) to have a high acidity. Alkalinity is the capacity of water to neutralize acids. Water does not have to be strongly basic (high pH) to have a high alkalinity.

5.3.8 Salts

Chlorides, sulfates, potassium, calcium, sodium, and manganese are the most common *soluble salts* (ionic compounds) that are present in wastewater. Some of the salts may be removed during wastewater treatment. Other salts, such as ferric chloride and alum, are sometimes added to aid in wastewater treatment.

Soluble salts, especially sodium (Na^+), are important constituents of wastewater. When water containing high levels of sodium or other salts is land applied, there may be some swelling of clay minerals, which can reduce water movement through the soil. To reemphasize this point, salts reduce both infiltration (at the surface) and water movement through the soil (under the surface). This tendency occurs when the ratio of sodium to other *cations* (positively charged particles) is high. This relationship is called the *sodium adsorption ratio* (SAR) of a wastewater sample or soil extract. For recycled water with high levels of sodium or SAR, the soil conditions should be routinely checked for infiltration problems (especially with heavy clay soils).

5.4 Hydraulic- and Constituent-Loading Rates

Three factors must be considered for loading rates: hydraulic-loading rate , constituent-loading rate, and land-limiting constituent; these factors are discussed below. Other sources of water (e.g., supplemental water) may add to the overall hydraulic- and nutrient-loading rates.

5.4.1 Hydraulic-Loading Rate

For land application systems, the *hydraulic-loading rate* is the combination of all water (precipitation, recycled water, and any additional irrigation water) applied to a land application site. Example units of measurement include *gallons per acre* and *acre-inches*. (An acre-inch is the volume of water covering 1 acre of land to a depth of 1 inch and is equal to 27,154 gallons.)

Reuse permits specify hydraulic-loading rate limits for the *growing season* and *nongrowing season* (NGS). A site's growing season is identified by climatic conditions, which vary throughout the state. Typical growing season dates are April 1 through October 31, and typical nongrowing season dates are November 1 through March 31.

The growing season hydraulic-loading rate is typically specified to be substantially at the *irrigation water requirement* (IWR) of the crop (the water requirement of the crop). The calculation methodology for the IWR is covered in section 14.

For those permits allowing NGS land application, the NGS hydraulic-loading rate is generally limited to that given by Equation 5-2.

$$\text{Maximum (NGS) Hydraulic Loading Rate} = \text{Available Water-Holding Capacity of the Soil} + \text{Evapotranspiration in the NGS} - \text{Average Precipitation in the NGS}$$

Equation 5-2. Calculation of maximum hydraulic-loading rate.

An important objective of a land application system is to assimilate and treat all applied recycled water, supplemental irrigation water, and expected precipitation. The primary concerns with hydraulic overloading at a land application site are leaching of contaminants into the ground water and surface runoff along with a reduction in biological activity in the soil due to saturated soil. Surface runoff causes soil erosion and has the potential to impact nearby surface waters. To prevent runoff from a land application site, hydraulic-loading rates should not exceed the soil infiltration rate.

For sites that land apply during the NGS, it is particularly critical in winter months to not exceed the soil infiltration rate to prevent leaching of contaminants below the root zone and to prevent runoff from the site that may be accelerated due to freezing conditions and ice buildup. During the growing season, the health of the crop may be adversely affected with either excessively high or low hydraulic-loading rates. Hydraulic-loading rates above permit rates must be avoided to prevent leaching of contaminants to the ground water and runoff. Contact the DEQ regional office if hydraulic loadings above permit limits are needed to avoid lagoon overtopping or other emergencies.

5.4.2 Constituent-Loading Rates

The loading rates of constituents are important operating factors at a land application site. Constituents that are typically evaluated include nitrogen, phosphorus, NVDS (salts), and COD. The loading rates for nitrogen, phosphorus, NVDS, and COD are defined as the rate at which these constituents are applied to the site. Loading rates for nitrogen, phosphorus, and NVDS are generally given in pounds per acre. The COD loading rate is generally evaluated as an average daily loading rate (pounds per acre per day) during the growing season and nongrowing season.

5.4.2.1 Nitrogen

The assimilative capacity for nitrogen (N) is an important part of a land application treatment system because it may be a health concern if it leaches to ground water and violates permit requirements. Nitrogen removal can be very efficient in a soil-crop system. Efforts must be made, however, to control the leaching and runoff losses of nitrogen compounds. Conditions of rapid water movement beyond the root zone, which can occur with excess water application to soils, can lead to leaching and increased nitrate levels in ground water; approaches to mitigating such effects include the following:

- The basic approach to reduce leaching is to have crops that use nitrogen at the rate applied. This approach will help prevent excess nitrate accumulation and potential leaching problems and subsequent ground water pollution.
- The basic approach in controlling runoff is to apply runoff control technologies including hydraulic-loading rates not exceeding the soil infiltration rate, uniform sprinkler application, and using runoff control structures, such as berms and ponds.
- If nongrowing season application is allowed, the goal is to retain the nitrogen applied in the soil column and make it available for crop uptake the following growing season.

5.4.2.2 Phosphorus

Phosphorus (P) is a required crop nutrient. It is also a major contributor of pollution to streams, causing algae blooms, low DO, undesirable plant growth, and fish kills. Phosphorus can reach streams by runoff from land application sites or by inflow from aquifer recharge of the stream (ground water/surface water interconnection); mitigation strategies include the following:

- To protect surface waters from the effects of excess phosphorus, surface runoff and deep percolation of phosphorus must be controlled.
- Surface runoff concerns may be prevented or mitigated by applying runoff control technologies.
- Phosphorus impacts to surface water from deep percolation and ground water interconnections may be prevented or mitigated by managing the phosphorus-loading rate and phosphorus accumulation in the soil.

5.4.2.3 Chemical Oxygen Demand

COD is a common measure of organic matter being land applied. Most reuse permits in Idaho have a maximum COD loading rate of 50 lb/acre-day, averaged over the growing season. If nongrowing season application is allowed, the COD loading rate is normally limited to 50 lb/acre-day or less. Soils are a good medium for the assimilation of the organic matter in wastewater. Excessive COD loadings, however, can limit infiltration as a result of soil clogging, create anaerobic conditions, and reduce the site's ability to treat recycled water. Clogging generally occurs in the top few inches of soil and reduces water infiltration rates and can lead to higher runoff rates. Anaerobic conditions reduce aerobic treatment processes and may cause odor problems.

5.4.3 Land-Limiting Constituent

Wastewater from most domestic and commercial sources contains low concentrations of nitrogen, phosphorus, COD, and other constituents, such as TDS. For these wastewater streams, the amount of recycled water that can be applied to a treatment site is typically limited by the hydraulic-loading rate (*hydraulically limited)*, based on crop water requirements.

With higher strength wastewaters, however, the amount of applied water may be limited by the amount of nitrogen, phosphorus, NVDS, or COD, for example, in the recycled waterstream. This land-limiting constituent then dictates the amount of recycled water that may be land applied. In these cases, sites typically use supplemental irrigation water to ensure the crop is receiving adequate moisture for crop health.

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6 Soil Monitoring and Reporting and Management for Agronomic Nutrient Uptake

Need-to-Know Criteria
Soil components and profiles
Soil physical characteristics: soil texture, organic matter content, soil depth, soil drainage or wetness, and topography and landscape position
Soil chemical characteristics: sodium adsorption ratio and pH
Soil moisture: saturation, field capacity, wilting point, plant-available water content, available water-holding capacity, infiltration, and permeability
Fate of water constituents
Soil treatment of recycled water: physical, chemical, and biological treatment processes
Agronomy: factors that influence nutrient availability, levels of nutrient availability, fate of nutrients applied to soils, components of a nutrient management plan, and agronomic rate
Crop nutrient requirements: typical crop uptake

The WWLA operator must know what soil and crop monitoring is required to appropriately manage the reuse site. The final treatment component of a land application system is the soil. Along with its associated vegetation, the soil functions as a natural treatment system. Because many of the constituents in recycled water are nutrients that can be used productively by plants and microorganisms, well-managed land application systems can benefit the soil-crop system.

6.1 Soil Components and Profiles

Soil characteristics important to land application include composition and profile.

6.1.1 Soil Composition

Soil is a porous mixture of the following components:

- Organic material (highly decomposed plant and animal material [humus])
- Mineral material (weathered rock, sand, silt, and clay)
- Water
- Air

A medium-textured mineral soil contains approximately one-half soil solids (mineral and organic material) and one-half pore space (air and water). The volume occupied by each component in a medium-textured soil is approximately 46%–49% mineral matter, 20%–30% air, 20%–30% water, and 1%–4% organic matter (Figure 6-1). The relative proportions of these components vary within any given soil and from soil to soil, and they are important factors to consider when evaluating a soil for land application purposes.

The amount of pore space in a soil determines the volume of air or water that can occupy a given soil. As rainfall or water is added to and lost from a soil, the amount of pore space occupied by either air or water will vary. The type and amount of solids determine the physical and chemical filtering capacity of the soil. This filtering capacity makes soil an excellent medium for recycled water treatment.

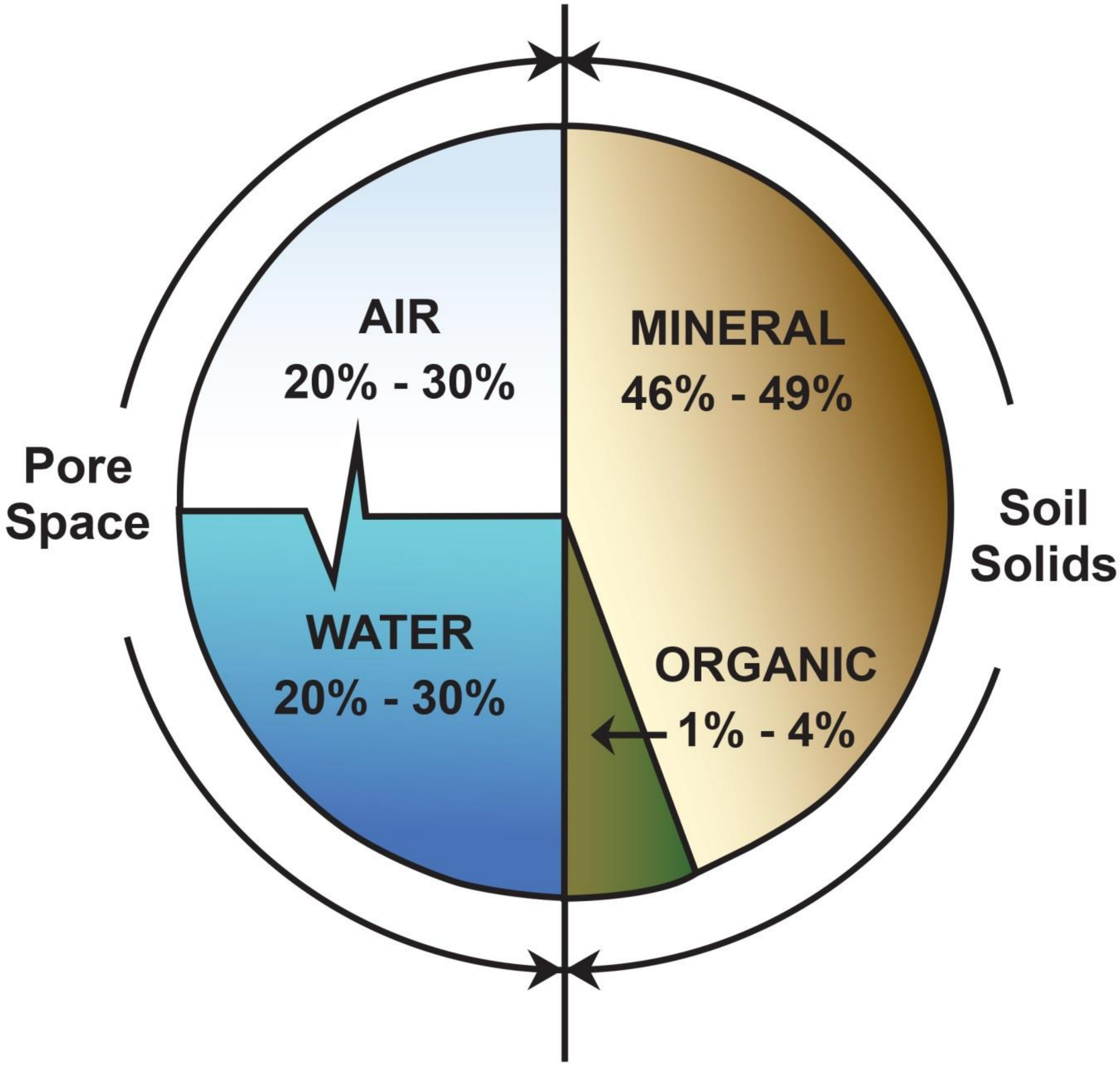

Figure 6-1. Composition of a medium-textured mineral soil (modified from Brady 1990).

6.1.2 Soil Profiles

Soil is a three-dimensional body, resulting from the physical, chemical, and biological weathering of bedrock, or from the accumulation of materials weathered elsewhere and transported to a site. As soil develops on the landscape, distinct layers, or *bands*, are formed parallel to the earth's surface. These layers or bands are called *soil horizons*.

Soil horizons are soil layers that differ from the overlying and underlying layers in some property, such as color, clay content, and abundance of cracks. A *soil profile* is a vertical slice of the soil showing the different horizons and their thickness (Figure 6-2).

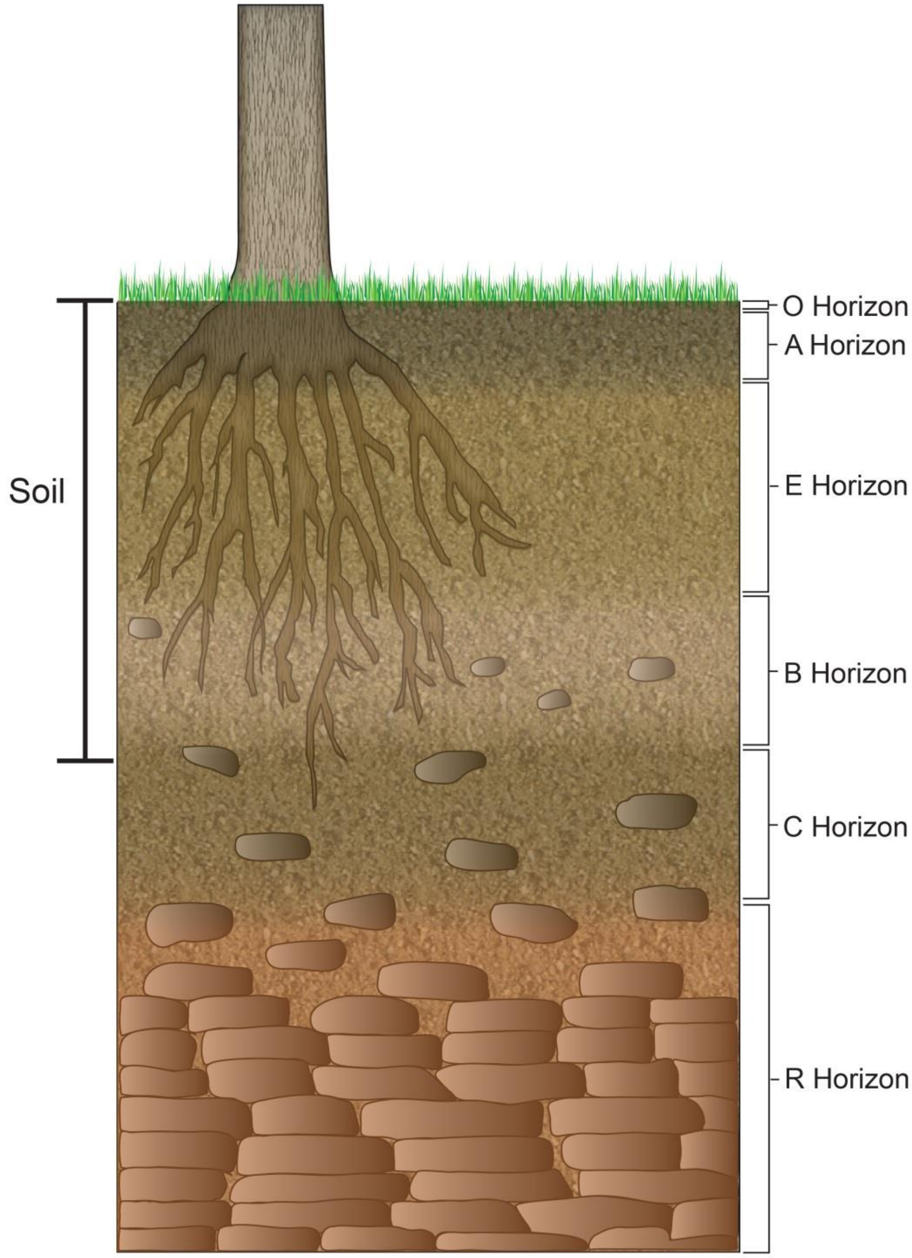

Figure 6-2. A typical soil profile and horizons (modified from Brady 1990).

Horizon designations differ from country to country. In the United States, soil horizons are designated by a code of letters and numbers developed by soil scientists of the National Cooperative Soil Survey. *Master horizons* are major layers designated by capital letters, such as O, A, E, B, C, and R. These master horizons are as follows:

- O horizon—Dominated by organic material from plants and animals. O horizons are usually present on the soil surface, except in the case of peats and mucks, where the O horizon extends almost to the bottom of the soil.
- A horizon—Present at the soil surface or just below the O horizon. These horizons may contain some organic material mixed with mineral material. Properties of an A horizon

may reflect plowing, pasturing, or similar activities. The A horizon is generally the zone of maximum biological activity in a soil.
- E horizon—Characterized by loss of clay, iron, and aluminum oxides from leaching; sand and silt-sized particles of resistant minerals, such as quartz, remain. The E horizon is generally lighter in color than the overlying A horizon.
- B horizon—Exhibits layers of accumulation of clay, iron, and aluminum oxides that have migrated from overlying E horizons. The B horizon reflects the subsurface layer of greatest development for that particular profile.
- C horizon—Consist of unconsolidated, partially weathered material that is neither rock nor soil. Little to no biological activity takes place in this horizon. The upper portion may become part of the B horizon as weathering continues.
- R horizon—Consists of underlying bedrock. It may not occur in coastal plain soils or other soils formed in transported material, such as floodplains.

Soil profiles with similar characteristics or properties are classified as a *soil series*. A soil series includes soil that has developed from similar materials and processes, resulting in similar soil profiles. Because soil profiles vary so widely from place to place, many different soil series have been identified. (Approximately 17,000 soil series are found in the United States alone.) The characteristics of the soil series present at a proposed treatment site will determine if the site is suitable for the application of recycled water.

6.2 Soil Physical Characteristics

A number of physical soil characteristics affect water treatment at a land application site. While some of these characteristics can be altered, others cannot. Physical characteristics include the following:

- Soil texture
- Soil structure
- Organic matter content
- Soil depth
- Soil color
- Soil drainage/wetness
- Topography and landscape position

6.2.1 Soil Texture

The mineral particles in a soil are divided by size into three groups: sand, silt, and clay (Figure 6-3). Soil texture refers to the relative proportion of sand, silt, and clay in a given soil. The diameters and characteristics of these soil particles are described in Table 6-1.

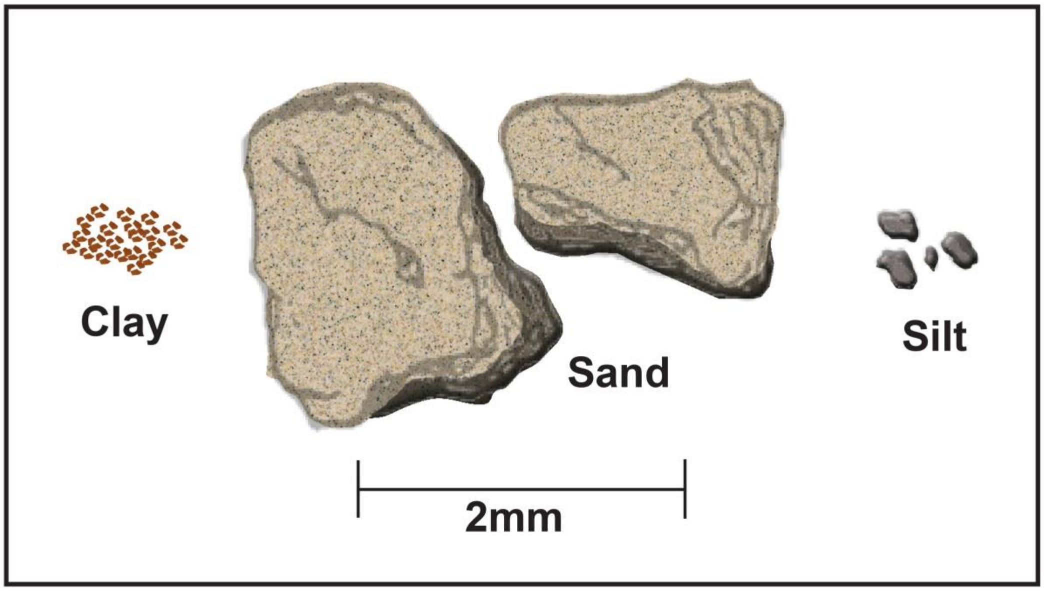

Figure 6-3. Representation of the comparative sizes and shapes of sand, silt, and clay particles (modified from Hillel 1980).

Table 6-1. Size and general characteristics of the three soil particle types.

Particle Type	Particle Size (millimeters)	General Characteristics
Sand	2.0–0.05	Individual grains visible to the eye, gritty when soil is rubbed between the thumb and fingers.
Silt	0.05–0.002	Smooth and baby-powder feel when rubbed between the thumb and fingers. Not plastic or sticky when moist.
Clay	< 0.002	Smooth, sticky, and plastic feel when moist. Forms very hard clods when dry. Particles may remain suspended in water for extended periods of time.

The United States Department of Agriculture (USDA) currently recognizes 12 distinct textures or textural classes, as shown in the USDA Soil Textural Triangle (Figure 6-4). The three sides of the triangle are broken into percentage units (0–100%) of sand, silt, and clay. To use the triangle, locate the percentage of clay and project inward as shown by the arrow. Do likewise for the percent silt (or sand). The point at which the two projections intersect identifies the textural class name.

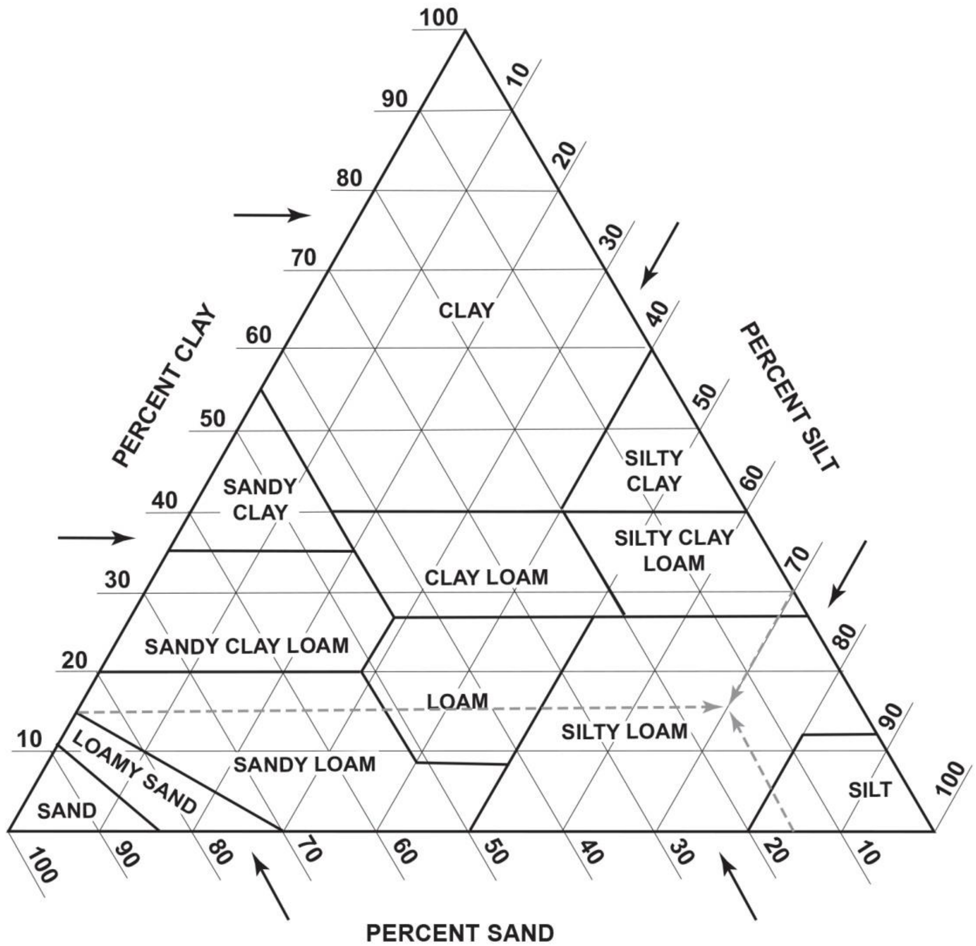

Figure 6-4. Textural triangle: the major soil textural classes are defined by the percentage of sand, silt, and clay according to the heavy boundary lines shown on the textural triangle. The example shown by the dotted arrowed lines represents a soil with 15% sand, 15% clay, and 70% silt. The resulting soil class is located where the three arrows meet and is inside the heavy boundary labeled silt loam (Brady and Weil 2008).

Four of the textural classes are considered to be major groups: *sand*, *silt*, *clay*, and *loam*.

Note that all of the textural classes contain some sand, silt, or clay. For example, a soil containing over 55% clay-sized particles is considered a clay soil regardless of the fact that it also contains significant proportions of silt- and sand-sized particles. The remaining eight textural classes are combinations of two or three of the major groups.

A textural class can consist of one, two, or three names. Classes with two or three names, such as sandy loam or sandy clay loam, fall in between the major groups. The last word in the name always represents one of the four major groups. The first or the first and second words are modifiers that tell where the soil texture lies on the triangle relative to the other major groups.

For example, a *sandy loam* is a loam that is sandy. It lies on the side of the loam nearest the sand group. Focusing on the four main groups of the textural triangle, the modifiers can be used to judge where the textural class of a material lies in relation to the four major groups. Answers to questions such as "What contains more sand: a sandy loam or a loamy sand?" should then be obvious.

Texture can be determined in a laboratory using either sieve or hydrometer analysis. Sieve analysis is based on physical passage of soil particles through a series of standard mesh screens, while hydrometer analysis is based on variations in settling time for the different soil particle sizes. Texture can also be determined in the field by using the *feel method* (Figure 6-5).

Texture is an important soil characteristic because it strongly influences the retention of water, nutrients, and pollutants. Coarsely textured soils, such as sands and loamy sands, have large spaces (*macropores*) between their soil particles. Water and air pass through these macropores rapidly. Therefore, coarsely textured soils are usually well-aerated and well-drained. However, water often passes through these soils too quickly for significant treatment to occur. In addition, these soils may not hold sufficient water and nutrients to support a healthy vegetative cover. A poor vegetative cover can result in an increased potential for erosion and reduced uptake of water, nutrients, and pollutants.

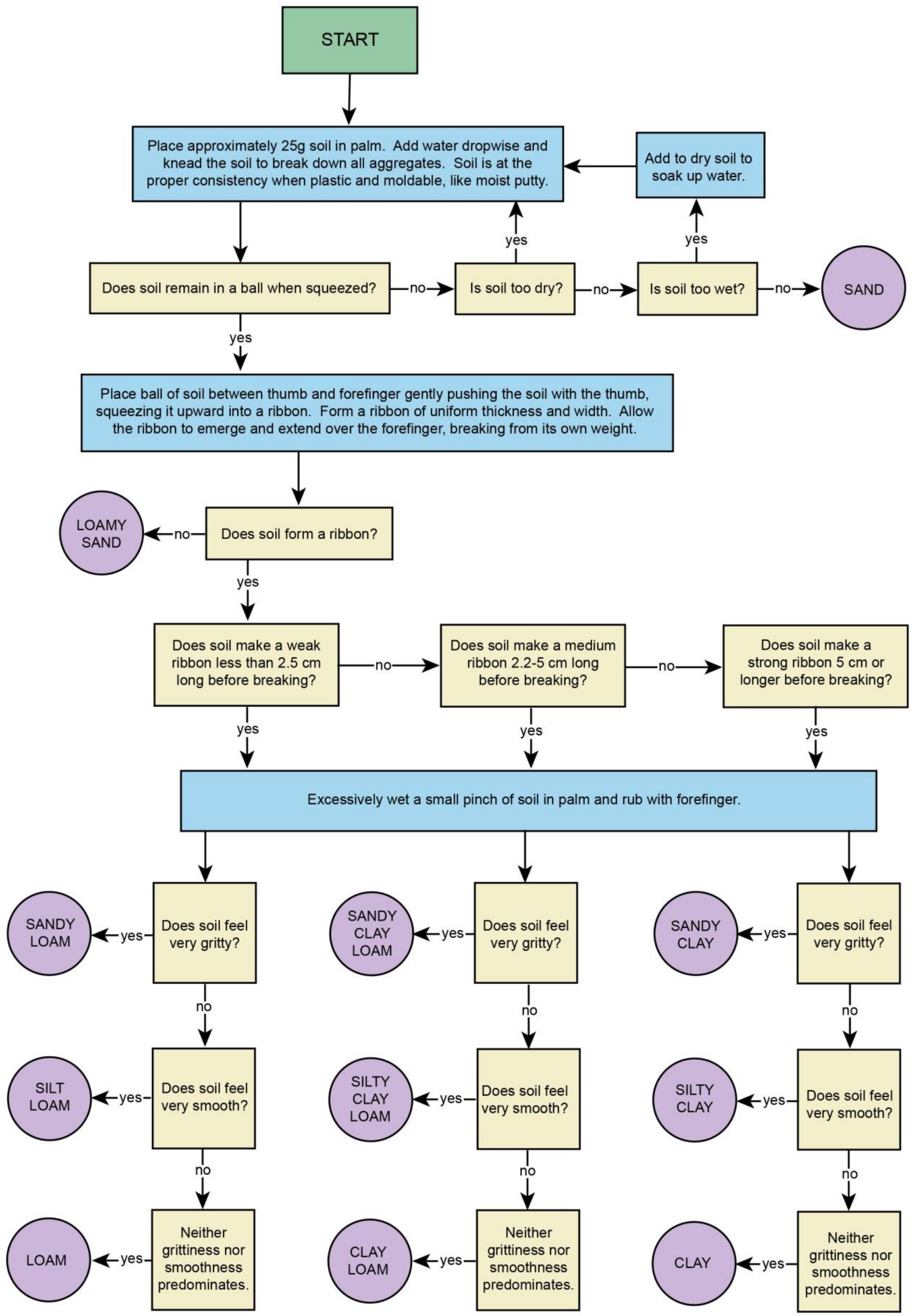

Figure 6-5. Diagram for determining soil textural class by *feel* (modified from Thien 1979).

Finely textured soils, such as clays, sandy clays, and silty clays have smaller spaces (*micropores*) between soil particles. Due to cohesive and adhesive forces, micropores hold water, nutrients and pollutants more tightly than macropores. Therefore, water tends to move into and through finely textured soils more slowly. Wastewater may pond on the soil surface, causing runoff. If a sandy soil horizon is underlain by a clayey horizon, wastewater may move into the sandy surface horizon but not through the clayey subsoil. Water may *perch* on top of the clayey horizon and move laterally, emerging downslope and causing runoff.

Therefore, when evaluating a soil for land application, the texture of all the horizons needs to be considered. Water movement, treatment, and plant rooting patterns are often influenced by several horizons. Many problems associated with land application can be predicted by determining soil textures throughout the profile.

Because texture of a soil horizon is the relative proportion of sand, silt, and clay, it may be changed only through the addition of one of these soil separates; the addition of organic matter will not change the soil texture, but it may change the way the soil feels. However, modification of soil texture is not practical on a large scale.

6.2.2 Soil Structure

Along with soil texture, *soil structure* is one of principle factors that influences the rate of water movement. Soil structure refers to the arrangement of individual soil particles (sand, silt, and clay) into more complex aggregates or *peds*. These peds can be separated from each other along natural planes, zones, or surfaces of weakness into distinct units.

Ped units may be granular, blocky, subangular blocky, columnar, prismatic, or platy (Figure 6-6). Soils that do not form structural units, such as very sandy soils, are considered structureless. Soils that do not naturally separate into structural units, such as very sticky clayey soils, are considered to have massive structure. Granular structure is often present in the A and E horizons, while other types of structure are generally found in the lower horizons.

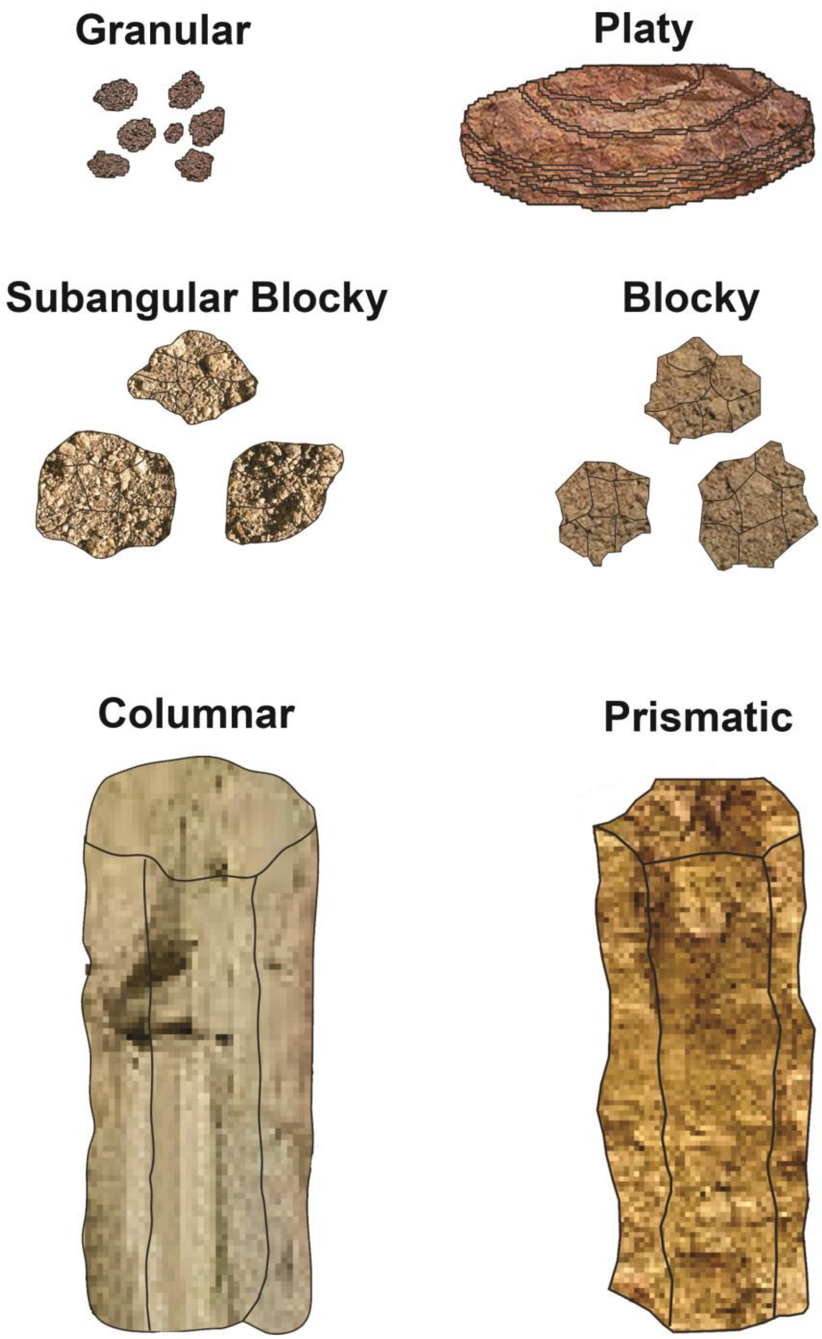

Figure 6-6. Various structural types found in mineral soils (modified from Hillel 1980).

Soil structure affects water movement, both into and through the soil. Because water moves primarily between peds, soil structure can modify the influence of soil texture on water movement:

- As previously discussed, water movement in finely textured soils can be very slow, but clayey soils with well-developed blocky and subangular blocky structure can transmit reasonably large volumes of water between peds, although these soils are finely textured.

- In finely textured soils with massive structure, (the clay is so sticky that individual peds do not form); water movement can be expected to be slow and restricted. Water movement can also be slow in soils with some platy, prismatic, or columnar structure.

Unlike texture, structure can be easily altered by management practices. Additions of organic matter can improve soil structure by acting as a binding agent for soil particles. Unfortunately, changes in soil structure are usually negative. If finely textured soils are traveled with heavy equipment, tilled, or otherwise worked when wet, soil aggregates are destroyed and macropores disappear, resulting in *soil compaction*. In this condition, water and air cannot move through the soil. Even after the soil dries, structure remains destroyed. It is very important to keep heavy equipment off of land application fields when wet to avoid compacting the soil.

6.2.3 Organic Material Contents

Soil organic matter (humus) is composed of decomposing plant and animals and waste materials produced by soil microorganisms. The organic matter content of most mineral soils is generally less than 4%. However, organic matter serves several important functions in soil-crop treatment systems:

- Organic matter promotes soil structure formation in finer-textured soils. Good soil structure aids water movement in soil by increasing the pore space.
- In sandy soils, organic matter helps fill larger pores and increases the soil's ability to hold water, nutrients, and pollutants, thus increasing its treatment potential.
- Organic matter is a food source for soil microorganisms. Microbial activity, in turn, produces waste products that promote soil structure formation.
- Organic matter contains several plant nutrients, particularly nitrogen, phosphorus, and sulfur. As organic matter decays, these nutrients become available for use by plants and microorganisms.
- Organic matter has a high negative charge, which increases a soil's ability to retain water, nutrients, and pollutants.

6.2.4 Soil Depth

Soil depth refers to the thickness of the soil horizons, from the soil surface to a depth that restricts plant root growth or otherwise limits biological activity. The plant rooting depth or root limiting depth (whichever is less) is generally used to determine the hydraulic loading limits in a reuse permit and is also used by the operator to design and manage irrigation schedules. This limiting depth is often caused by a restrictive horizon in the soil. A restrictive horizon could be a seasonal or permanent water table, layer of gravel, weathered or unweathered bedrock, chemical change, or soil structural change that limits the depth of biological activity.

Soil depth is important for the following reasons:

- It determines the volume of soil that is available for the treatment of recycled water.
- It affects the type of plants that can be grown on the site.

6.2.5 Soil Color

Soil color is an indicator characteristic that is used to predict soil-water relationships in a soil profile. Soil color is an extremely useful tool when evaluating a site for suitability as a land treatment system.

Soils that are well drained typically have rather bright colors due to oxidized or ferric iron (Fe^{+3}). Ferric iron imparts a reddish/orange color to the soil. When soil drainage is impeded, and the soil is saturated, the ferric iron contained in the soil is chemically reduced to ferrous iron (Fe^{+2}). Ferrous iron is soluble in water, and as the water table recedes, this soluble iron is removed, leaving behind soil that is gray in color.

As the water table rises and falls, a characteristic pattern called *mottling* usually develops. Mottled soils generally contain bright orange and red areas mixed with light gray areas. These mottle patterns are impressed upon the original background, or matrix color, of the soil.

The presence or absence of gray mottles or color in a soil is an indication of the wetness or aeration status of the soil:

- Bright, uniform colors indicate that a soil is well drained and that a seasonal high water table is not present for a significant time during the year.
- The presence of light grayish mottles usually indicates a high water table or poorly drained soil. The depth to gray colors can be used to define the drainage class of a soil and indicate the depth of the seasonal high water table.
- Soils with gray mottling near the soil surface are not generally suitable for land application because saturated soil conditions are not conducive to land treatment, may move constituents to ground water, and may limit the type of plants and adversely impact plant health.

Soil color is determined by using an international color standard, the *Munsell* system. This standard was developed to describe colors and to avoid confusion that can arise by describing a color as simply red or yellow. The Munsell system uses three components of color to describe coloration within a soil—*hue*, *value*, and *chroma*:

- Hue is the dominant spectral color (red and yellow).
- Value describes the degree or darkness or lightness.
- Chroma refers to the purity or strength of the color.

A moist soil sample is compared to the color chips in a Munsell color book to identify the most appropriate match.

6.2.6 Soil Drainage/Wetness

Soil *drainage* or *wetness* refers to the depth of the water table and to the period of time a particular part of the soil profile is saturated. A soil may be classified as *well drained*, *moderately well drained*, *somewhat poorly drained*, *poorly drained*, or *very poorly drained*.

Poorly drained soils have a water table at or within 12 inches of the soil surface for most of the year. Well-drained soils have a water table depth of 60 inches or more during much of the year.

The drainage class of a soil can usually be determined by observing both the color patterns of the soil profile and the soil's relative position on the landscape.

Poorly drained and very poorly drained soils are not generally considered suitable for land application for several reasons:

- Wet soils do not provide adequate treatment capacity, and waste constituents may move directly to ground water.
- Seasonally wet soils may limit the type of plants that can be grown on the site and can impact the quality of the vegetative cover.
- Wet soils are subject to compaction by equipment traffic that destroys soil structure and reduces the infiltrative capacity of a site.

The drainage class of a soil refers to water table depth, not permeability (section 6.4.3). Consequently, although a soil might be coarsely textured and relatively easily drained, a high water table due to landscape position can render the soil poorly drained. If an outlet or a drainage system is provided for soil water, then this poorly drained sandy soil may be modified. However, installing any type of drainageway or drainage system at a land application site is not recommended because it could be a violation of the system’s permit conditions.

6.2.7 Topography and Landscape Position

Topography refers to the configuration of the land surface and is usually defined by the slope of the land (steepness). *Landscape position* refers to a specific *setting* on the landscape. Examples of landscape positions include the following:

- Upland or ridgetop
- Sideslope
- Shoulder slope
- Footslope
- Depression
- Floodplain

The topography and landscape position of a site are important because they influence the types of soils that may be present, respective depth of those soils, and water movement characteristics of the site. Slope considerations also dictate how a site can be managed and whether land application is even possible. Land application is generally not acceptable on steep slopes. Fields with more slope will require more management practices to prevent soil erosion and runoff.

Topography influences surface water removal, whereas landscape position influences ground water flow. Topography is an important consideration when managing a site. Your specific site dynamics as they relate to water flow should be understood; for example, steep slopes may encourage runoff and erosion, while nearly level sites may encourage ponding or seasonal high water tables.

Figure 6-7 shows cross-sectional and plan views of different landscape positions. In foot slope and head slope positions, surface water converges with a corresponding increase in ground water flow. At these positions, springs or seeps of water coming out of the ground can be expected. Since these sites accumulate water, they are often saturated. Additional flow from wastewater irrigation will compound the problems on these areas. Such areas may need reduced loading rates or may be excluded from land application.

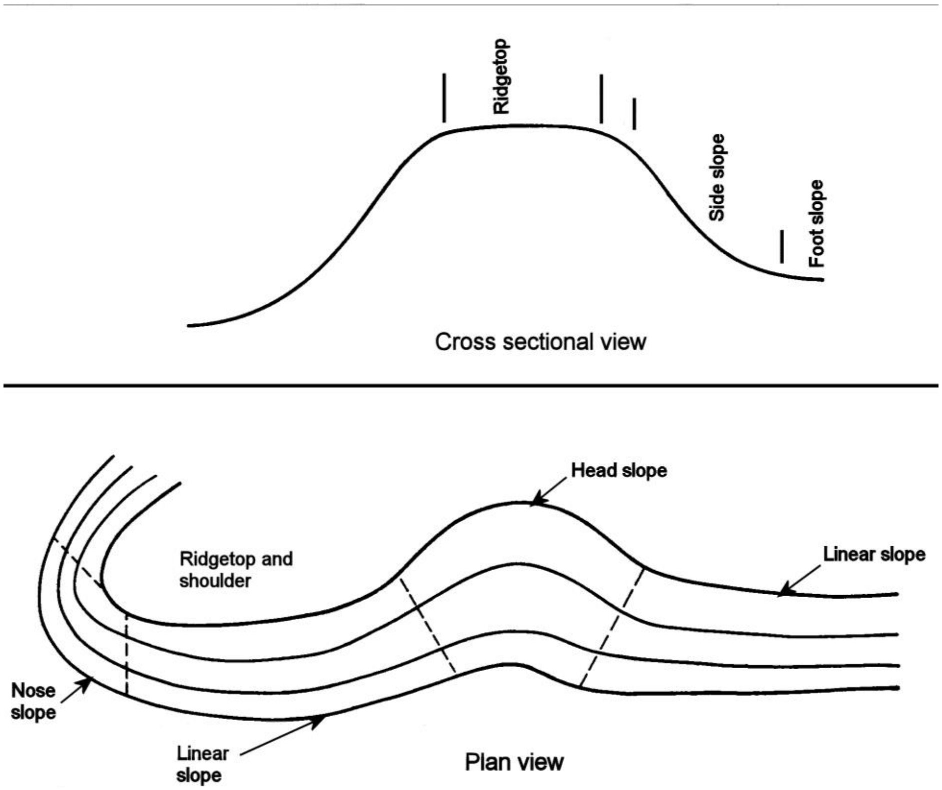

Figure 6-7. Cross-sectional and plan view of various landscape positions (Daniels et al. 1984).

The landscape positions called *ridge*, *shoulder*, and *nose slope* are typically the best suited for treatment. These positions shed water in a divergent manner, so that flow is not concentrated. This results in better infiltration and less runoff and saturation potential.

On a small scale, *microtopography* refers to minor variations across a landscape. A localized circumstance, such as a rock outcropping or wet depressional area may require additional buffer zones, but often such circumstances may not be extensive enough to rule out the usefulness of an entire site. Detailed site evaluations should define the topography and discuss any limitations of the site that are a function of topography.

6.3 Soil Chemical Characteristics

Soil chemical characteristics that affect recycled water treatment at a land application site include the following:

- Texture and organic matter content
- Cation exchange capacity (CEC)
- SAR
- pH

6.3.1 Texture and Organic Matter Content

Two of the physical soil characteristics discussed earlier, texture and organic matter content, also have important chemical properties. Clay-sized mineral particles and organic matter particles are both extremely small. Because of their small size, these particles expose a large external surface per unit mass. Put another way, their surface area to volume ratio is very large. The external surface area of 1 gram of clay is at least 1,000 times that of 1 gram of coarse sand. Therefore, these mineral and organic particles, called *colloids*, account for essentially all of the chemical reactivity of soils.

Mineral colloids (clay-sized particles) are crystalline in nature and consist primarily of aluminosilicate clays and oxides and hydroxides of aluminum and iron. Organic colloids (humus), composed of highly decomposed residues of plant and animal remains, contain carbon, hydrogen, and oxygen, along with minor amounts of nitrogen, phosphorus, sulfur, and other elements.

Mineral and organic colloids carry both positive and negative electrical charges. The charge and surface area of organic colloids greatly exceed that of mineral colloids. Organic colloids often contribute 30% to 90% of the total charge present in surface soils, even when present in relatively low amounts. The charged surfaces of all colloids are extremely important because of their ability to attract and repel both nutrients and waste constituents.

Variations in the types of clays (*clay mineralogy*) may also be a factor in the soil's ability to treat wastewater. Different types of clays have different structures that determine how the clay particles will absorb water and minerals. *Expansive clays* (also called *shrink/swell clays* or 2:1 clays), have a large internal surface area, resulting in a higher net negative charge than other types of clay particles. Therefore, these clays may hold a higher volume of constituents. However, they are subject to more wetness and site workability problems and generally are less suitable for treatment.

6.3.2 Cation Exchange Capacity

Ions are atoms or groups of atoms that are electrically charged as a result of the loss or gain of electrons. *Cations* are ions that have lost electrons and are therefore positively charged. *Anions* are ions that have gained electrons and are therefore negatively charged.

Soil colloids act like magnets, attracting and retaining anions and cations against the downward movement of water through the soil profile. The chemical attraction of cations and anions to soil colloid surfaces is called *adsorption* (not to be confused with absorption—the process by which ions are taken into plant roots).

For example, soil colloids that have a net negative charge, generally attract significantly more cations than anions (Figure 6-8). As a result, these soil colloids are generally surrounded by a swarm of adsorbed cations. The capacity of a soil to retain cations such as ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), zinc (Zn^{2+}), and copper (Cu^{2+}) increases with increasing negative charge of the soil colloids.

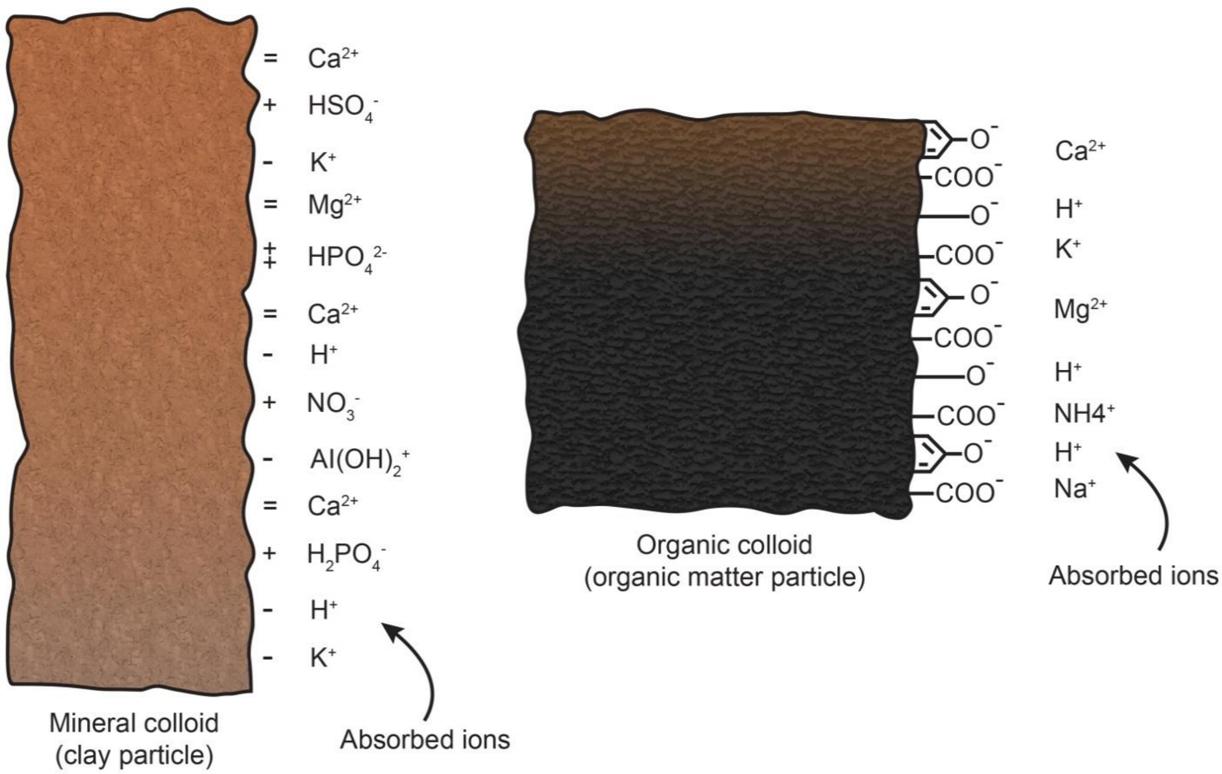

Figure 6-8. Mineral and organic colloids with adsorbed ions (modified from Brady 1990).

These adsorbed cations are also called exchangeable cations because they are subject to exchange with cations that are present in the soil solution (water moving through the soil). For example, a calcium ion (Ca^{2+}) adsorbed to a soil colloid can be replaced by two hydrogen ions (H^{+}) that are present in the soil solution. The cations forced into the soil solution by this exchange can then be used as nutrients by plants and microorganisms. If not assimilated by plants or microorganisms, these cations can leach or percolate downward to ground water.

The sum total of the exchangeable cations that a soil can adsorb is the CEC of that soil. CEC is expressed in units of milliequivalents per 100 grams of soil (meq/100 g) or in SI units, centimols per kilogram (cmol/kg), both expressions are equivalent. The CEC of a soil is related to its texture, clay mineralogy, organic matter content, and pH. Sandy soils have lower CECs than clay soils because sandy soils contain fewer colloidal particles than clay soils. As mentioned earlier, different types of clays have different structures and are able to adsorb different amounts of ions, thus affecting their CEC values. Soils with higher organic matter contents generally have higher CECs. The effect of pH on CEC values is discussed in section 6.3.4.

Soils with high CECs are able to adsorb more cations. They are better able to buffer or avoid rapid changes in levels of these cations or nutrients in the soil solution by replacing them as the soil solution becomes depleted of cations. Therefore, CEC values greatly influence the inherent fertility and long-term productivity of a soil. These values should be integrated with other site-related features to determine overall site suitability and application rates for land application sites. Figure 6-9 shows ranges of CEC values for different soils and soil materials.

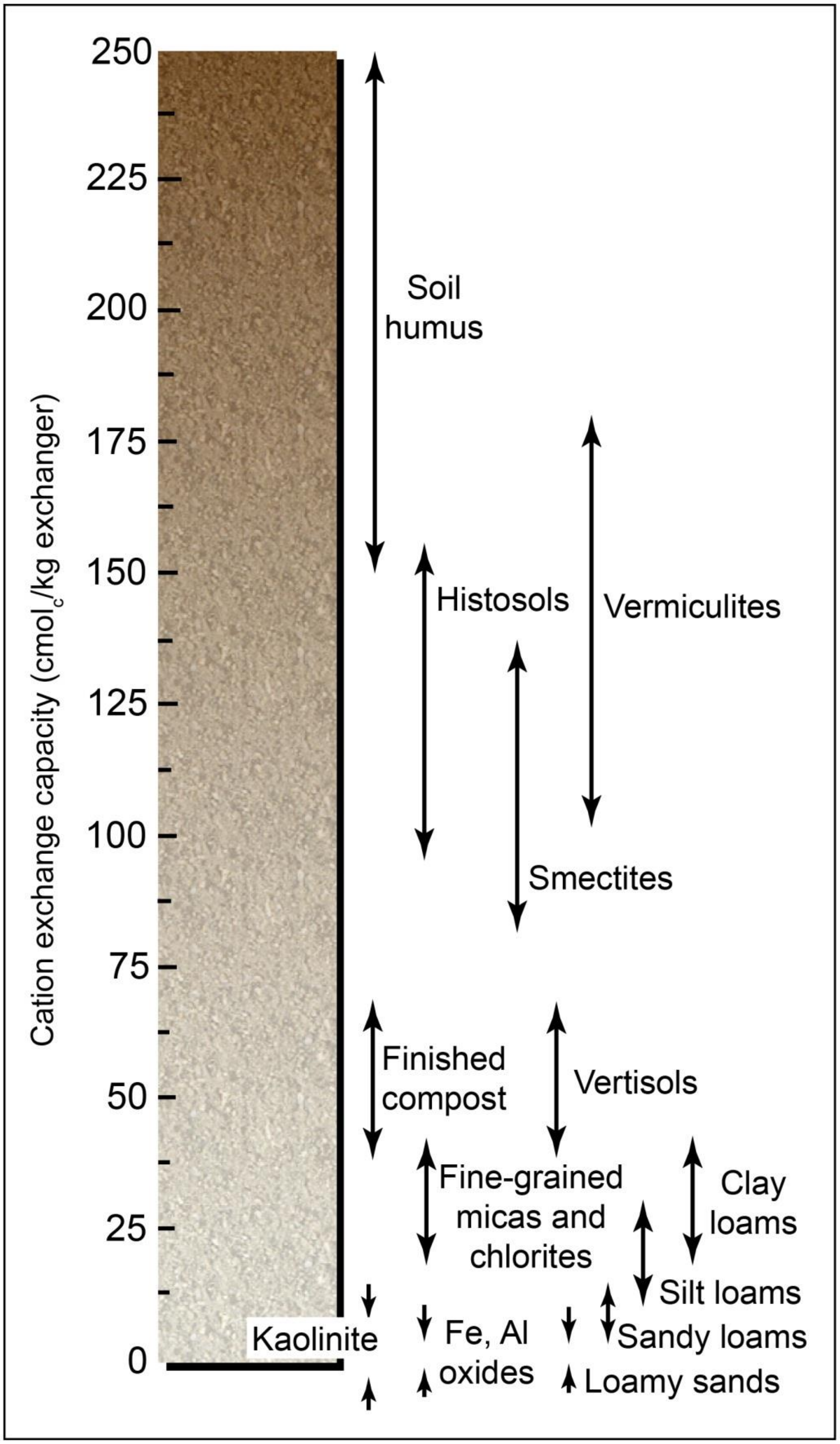

Figure 6-9. Ranges in cation exchange capacities (at pH 7) that are typical of a variety of soils and soil materials. The high CEC of humus shows why this colloid plays such a prominent role in most soils (diagram courtesy of R. Weil) (Brady and Weil 2008).

6.3.3 Sodium Adsorption Ratio

SAR serves as an index of the potential sodium influence in the soil. SAR values above 13 classify soils as *sodic* or alkali, have sodium as the dominant cation, and may possibly experience infiltration problems due to *deflocculation* (breakdown of peds) of soil colloids and decreases soil infiltration. Certain textures of soils can become affected at values lower than 13.

6.3.4 pH

As discussed in section 5.3.7, pH is the measure of the concentration of the hydrogen ions in a solution, and it indicates whether a soil is acidic (pH less than 7), alkaline (pH greater than 7, or neutral (pH equal to 7). pH is a critical soil property because it influences many of the chemical and biological reactions that take place in the soil. Figure 6-10 shows the range of various soil types compared to familiar substances. Idaho soils cover a wide range of soils. Northern Idaho soils and some central and northeastern Idaho soils can be represented with forest soils or humid regions arable soils shown in Figure 6-10. Southern Idaho, on the other hand, can be represented mainly by calcareous soils. Soil pH is not a constant, and for proper crop health, it may be necessary in northern Idaho to raise the pH and in southern Idaho to lower the pH. This may be done by using soil amendments such as lime (calcium carbonate) for raising pH and elemental sulfur for lowering pH. Additional discussion on pH is given in the agronomy section of this manual (section 6.7), which better discusses soil amendments, when to apply them, and typical application rates.

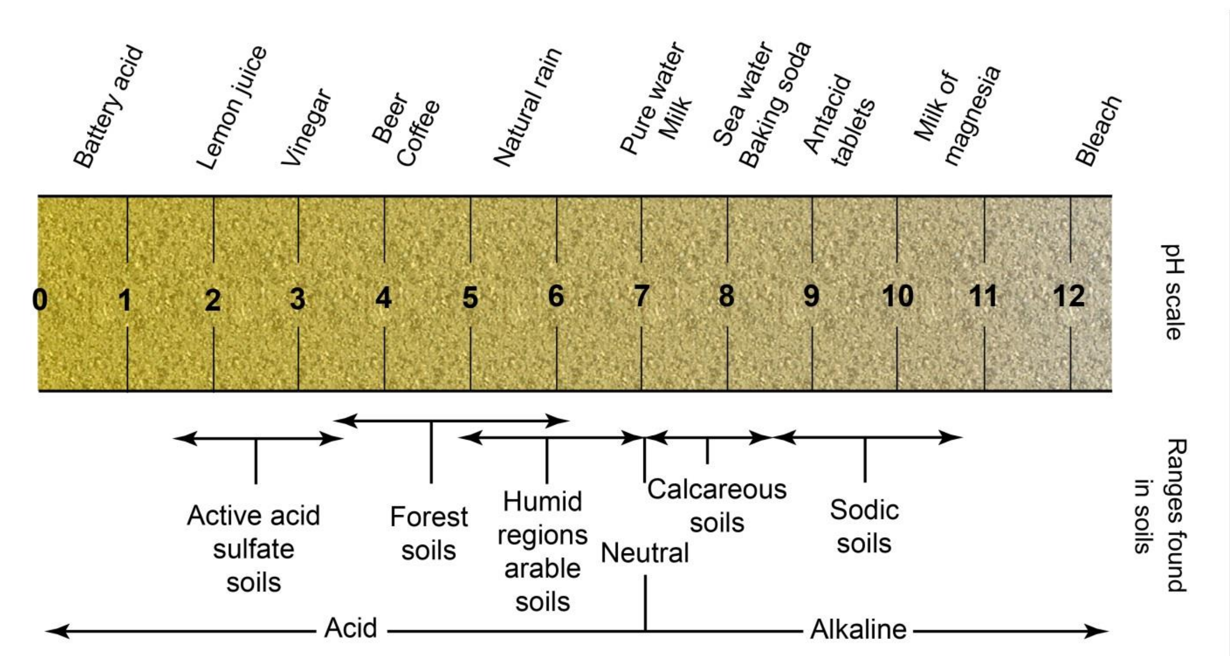

Figure 6-10. Some pH values for familiar substances (*above*) compared to ranges of pH typical for various types of soils (*below*) (Brady and Weil 2008).

The CEC of a soil is directly influenced by its pH. Mineral soils with a pH near 6 are generally the most efficient providers of plant nutrients, and crop health and yield are affected by pH. When the pH is below 6.0, the charge on a mineral colloid is relatively constant. However, a portion of the charge is pH dependent and increases when the pH is 6.0 or higher. The charge on organic colloids is almost completely pH dependent. Therefore, the CEC of most soils increases with an increase in pH.

Soil pH also influences the solubility of heavy metals and other nutrient cations and affects the ability of plants to uptake these metals and nutrients. Soils that are very acid (pH of less than 5.5) are more likely to release metals; plant uptake of these metals is prevented, and the potential for metals to move into the ground water is increased. Soil pH is also important for maximizing crop use of other available nutrients.

The bacteria that perform treatment in the soil are also strongly affected by soil pH. These bacteria prefer a pH of neutral (or 7) for best performance. Any rapid increase or decrease in pH can cause mortality in the bacteria population, resulting in poor water treatment.

Soil pH must be determined by laboratory analysis, although tools used to estimate pH in the field can be useful for general guidance.

6.4 Soil Moisture

Both the physical and chemical properties of a soil can change as moisture conditions change. To properly operate and maintain a land application system, an understanding of soil-water relationships is essential. Become familiar with the following soil moisture terms:

- Plant-available water (PAW)
- Infiltration
- Permeability

6.4.1 Plant-Available Water Content

Remember that a soil consists of soil particles and pore space. Pore space is filled with water, air (actually gases such as oxygen, carbon dioxide, and nitrogen), or both.

When all of the pore space is filled with gases, the soil is said to be *oven dry*. An oven dry soil is defined as a soil that has been dried at 105 °C until it reaches constant weight. An oven dry soil contains no water.

At the other extreme is saturation; a *saturated* soil has all of its pore space filled with water. At this point, the soil has reached its maximum retentive capacity (Figure 6-11).

Following rain or irrigation, a portion of the water held in the pores will drain from the soil due to gravity (*gravitational water*). After 1 to 2 days, the gravitational drainage will become negligible. At this time, the soil is said to be at *field capacity*. All of the water has been drained from the macropores and has been replaced by gases. The remaining water is found in the micropores. The micropores are small enough that the adhesive and cohesive forces holding the water to the pore wall are stronger than the gravitational force trying to drain the soil. Water held in the micropores at this point is available for use by plants.

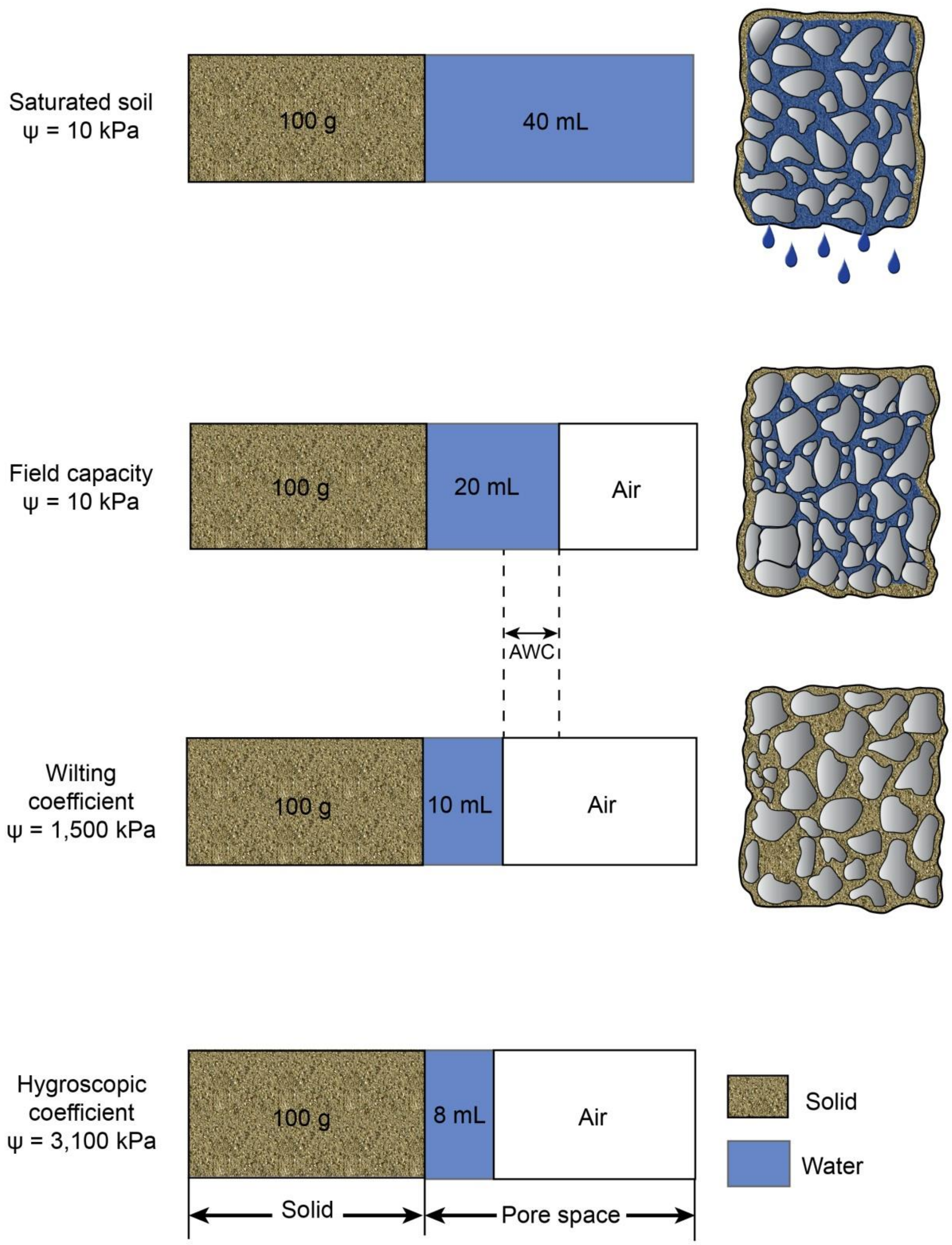

Figure 6-11. Volumes of water and air associated with 100 grams of a silt loam soil at different moisture levels. The top bar shows the situation when a soil is completely saturated with moisture. This situation will usually occur for short periods of time during rain or irrigation. Water will soon drain out of the larger pores. The soil is then said to be at field capacity. Plants will remove moisture from the soil quite rapidly until they begin to wilt. When permanent wilting of the plants occurs, the soil moisture is said to be at the wilting point. Considerable moisture is in the soil, but it is held too tightly to permit its absorption by plant roots (modified from Brady and Weil 2008).

As plants absorb water from the soil, they lose most of it through evaporation at leaf surfaces. Simultaneously water is evaporated from the soil. As the soil dries, the amount of water available to plants decreases. The initial response of plants is wilting. At the first onset of wilting, most plants recover during times of reduced evaporation (i.e., at night). As the soil continues to dry, the plants reach a point at which they cannot recover during periods of reduced evaporation. The plants are now in a permanently wilted condition and will die if water is not provided. This point is termed the *permanent wilting point*. The soil is not completely dry at this point, but the remaining water is held so closely by soil particles that it is not available for use by plants.

PAW content is the maximum amount of water a soil can make available to plants. It is defined as the difference between the water content at field capacity and the water content at the permanent wilting point. PAW is equal to the available water-holding capacity (AWC) of the soil, at a given root zone depth, expressed in inches of water per inch of soil, multiplied by the actual root zone depth, expressed in inches. Estimated AWC values can be found in the Natural Resources Conservation Service (NRCS) soils interpretation sheets or county soil surveys. PAW is different from AWC in that it is only the water content that exists in the root zone at a given time during plant growth, whereas, AWC is the total water content in the soil profile.

6.4.2 Infiltration

Infiltration is the movement of water *into* the soil. Infiltration rate is the maximum rate at which water enters the soil and is expressed in inches per hour. Infiltration rate is a function of the following:

- Soil texture
- Soil structure
- Soil moisture
- Vegetative cover
- Topography and landscape position

The effects of texture and structure on water movement have already been discussed. The more moisture a soil contains, the lower its infiltration rate. Infiltration rates decrease with the duration of rain or irrigation and increasing soil moisture. When the soil is completely saturated, the infiltration rate will be quite low.

A vegetative cover protects soil structure and increases infiltration rates. Without a cover, water falling on or flowing over the soil destroys the soil’s structure, resulting in an impervious surface crust. Level or gently sloping soils will have a higher infiltration rate than steeply sloping soils, which promote runoff.

Therefore, a dry sandy soil on a level slope with a good vegetative cover would be expected to have a high infiltration capacity, whereas a wet finely textured surface soil on a sparsely covered steep slope would be expected to have a low infiltration capacity and to promote runoff.

6.4.3 Permeability

Permeability refers to the movement of water *through* soil. Permeability is expressed in inches per hour. Soil texture and structure are the factors that most strongly influence permeability.

Generally, finely textured soils have slower permeabilities than coarsely textured soils. Permeability may also be called *hydraulic conductivity*.

Devices to measure permeability are available for field or laboratory use. Values for various soil permeabilities can also be found in NRCS interpretation sheets or county soil surveys.

6.5 Soil Treatment of Recycled Water

With a basic understanding of soil physical and chemical properties and soil-water relations, the mechanisms by which the soil and its associated vegetation function as a treatment system can be understood. The soil-crop system treats or renovates all sources of water and their constituents in the following ways (Figure 6-12):

- Physically
- Chemically
- Biologically

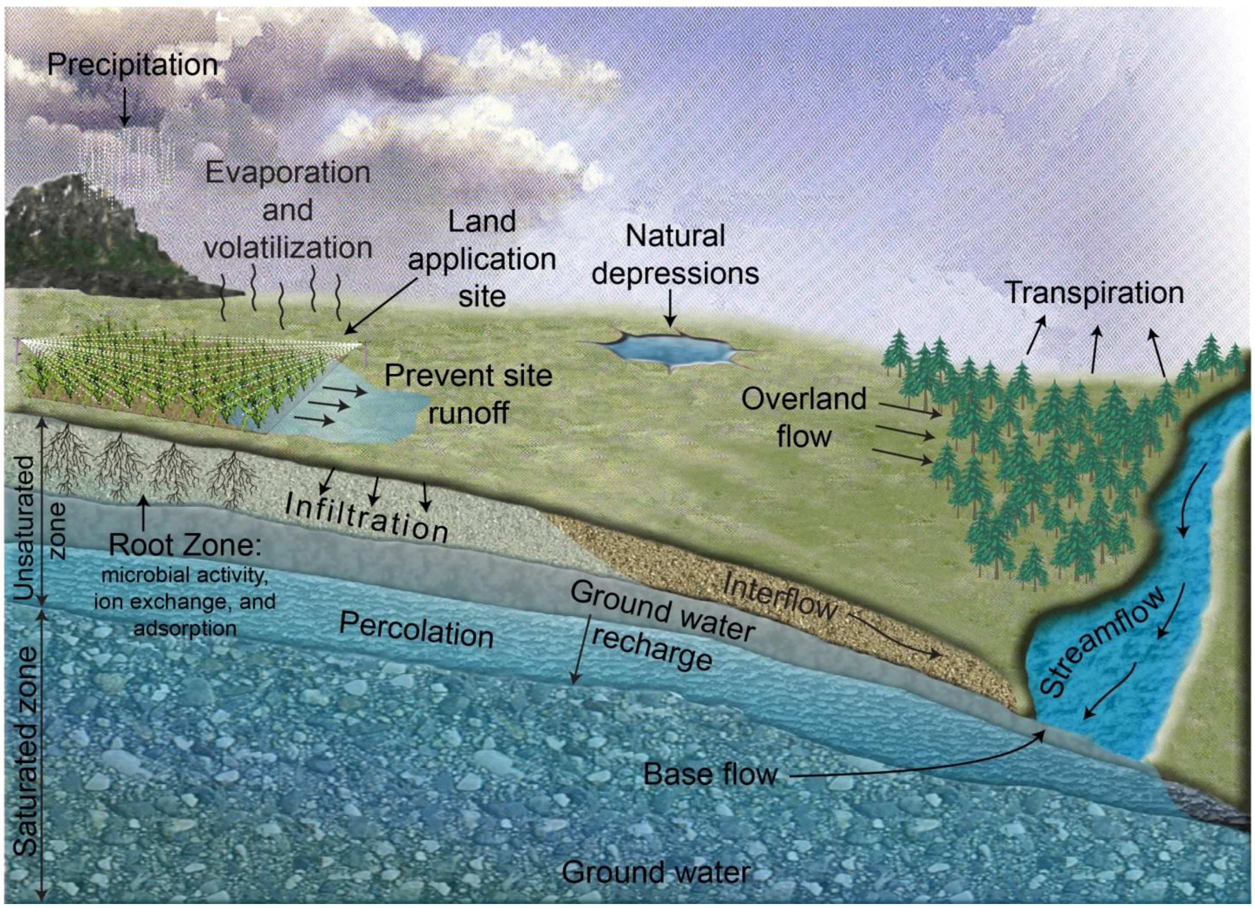

Figure 6-12. Soil treatment of recycled water.

6.5.1 Physical Treatment

The soil-crop system acts as a physical filter trapping particles in the soil pore spaces. Larger particles contained in water are screened or filtered out while smaller particles are allowed to pass through. As the soil collects more particles, the ability to screen smaller particles improves because the space between soil particles decreases. Any solid materials remaining after pretreatment are filtered from the recycled water during this process. These materials remain close to the soil surface where other treatment processes can occur.

Appropriate soil texture and structure are essential for optimum physical treatment. Obviously, a coarsely textured soil does not provide as good a filter as a finely textured soil because the pores are too large to trap constituents. On the other hand, a finely textured soil needs sufficient structural development to allow water to move downward through the profile at a moderate rate and to allow clayey subsoil layers the opportunity to trap or bind the constituents in the water.

6.5.2 Chemical Treatment

The soil-crop system also acts as a chemical filter. The following chemical processes can alter nutrients and constituents, such as inorganic chemicals, persistent organic compounds, and pathogens:

- Ion exchange—The transfer of ions between the soil solution and soil colloids. This exchange allows ions to move back and forth between the soil solution and soil colloids, becoming available for uptake by plants and microorganisms as needed.
- Adsorption—The bonding of ions to the surface of soil colloids by weak chemical reactions. Ions are held by the soil until taken up by plants or microorganisms. Viruses can also be adsorbed onto soil particles.
- Precipitation—A reaction in which an insoluble solid is formed from two or more soluble ions or compounds. For example, alum is often added to wastewater to remove phosphate by precipitation.
- Chelation—A process by which metallic ions are firmly bound by organic molecules; also called *complexation*. Organic molecules retain heavy metals as if held by a claw (the word chelate comes from the Greek word for *claw*). Although plants normally do take up the organic chelating agents, these agents apparently hold the metallic ions near plant roots until absorption of the ions can take place. While they are bound or *complexed* with the organic chelating agents, metallic ions are prevented from interacting with other compounds in the soil that could make them unavailable to plants.
- Volatilization—The chemical transformation of a substance into a gas that can evaporate or escape to the atmosphere. For example, under certain conditions, the ammonium form of nitrogen (NH_4^+) volatilizes to ammonia gas (NH_3), which can be released to the atmosphere.

A soil's ability to treat chemically depends on soil texture and structure, pH, soil temperature, organic matter content, and presence of clay or hydrous oxides. Finely textured soils with a pH greater than 6.5 provide the most effective chemical treatment.

6.5.3 Biological Treatment

The soil-plant system contains numerous living organisms, such as fungi and bacteria, that decompose or alter material placed on or in the soil. It is estimated that there may be as many as 8,000 pounds of microorganisms per acre in the first 6 inches of soil. Microorganisms alter or destroy water constituents through the following biological processes:

- Mineralization—The conversion of an element from an organic form to an inorganic form by microbial decomposition. For example, microorganisms attack organic nitrogen in the soil (present as proteins or amino acids). These microorganisms break down the complex organic compounds, releasing nitrogen in its inorganic forms (NH_4^+ and NO_3^-), also known as nitrification. It is the inorganic forms of most nutrients that are available for uptake by plants and microorganisms.
- Immobilization—The reverse of mineralization. Immobilization is the incorporation of an inorganic element into an organic form (plant or microbial tissue). Using nitrogen as an example again, inorganic forms of nitrogen (NH_4^+ or NO_3^-) are consumed by microorganisms and converted into organic tissue. The nitrogen is now bound up in the bodies of the microorganisms and is no longer readily available to other microorganisms or plants.
- Consumption—The use of organic matter present in waste as an energy source by microorganisms. Microorganisms feed and grow on constituents, resulting in the decomposition of these constituents. As the organisms grow and reproduce, more and more constituents are removed.
- Elimination—The process by which microorganisms destroy or alter pathogens or chemical compounds.
- Denitrification—The biological transformation of the nitrate and nitrite forms of nitrogen to gaseous nitrogen, which can escape to the atmosphere.

The soils ability to biologically treat depends on soil temperature, microorganism populations, chemical ratios (such as the C:N ratio), and the amount of organic matter present in the soil.

6.6 Fate of Water Constituents

Different water constituents are subject to different fates once they enter the soil-crop system. Nitrogen can be

- Mineralized
- Taken up by crops
- Immobilized
- Adsorbed onto soil colloids
- Lost as a gas to the atmosphere through volatilization or denitrification
- Leached to ground water, if not properly managed

Phosphorus can be

- Mineralized
- Taken up by crops
- Immobilized
- Adsorbed onto soil colloids
- Precipitated
- Leached to ground water, if not properly managed

Metals can be

- Mineralized
- Taken up by crops
- Complexed by chelates
- Adsorbed onto soil colloids
- Precipitated
- Leached to ground water, if not properly managed

Pathogens can be

- Consumed or eliminated by soil microorganisms
- Adsorbed onto soil colloids
- Complexed by chelates
- Killed by unfavorable environmental conditions
- Destroyed by exposure to ultraviolet light
- Leached to ground water, if not properly managed

Persistent organic chemicals can be

- Consumed or eliminated by soil microorganisms
- Absorbed by plants
- Chemically decomposed
- Adsorbed onto soil colloids
- Volatilized
- Broken down by ultraviolet light
- Leached to ground water

6.7 Agronomy

Plants are an integral part of the natural treatment system. It is important, therefore, that WWLA operators have a basic understanding of agronomy. Agronomy is the study of the various physical and biological factors related to crop production. While crop production is not the primary concern of a land application system, a healthy vegetative cover is essential for the natural treatment system to function properly. Important functions that plants perform include the following:

- Nutrient uptake
- Water consumption
- Enhance evapotranspiration
- Stabilize soil and prevent erosion
- Provide food and habitat for soil organisms that break down and use water constituents

6.7.1 Essential Nutrients

Although many factors affect the growth of plants, the WWLA operator has a great deal of control over the supply of essential nutrients. Plants require at least 16 elements for normal growth and for completion of their life cycle. Carbon, hydrogen, and oxygen are the elements used in the largest amounts; these nonmineral elements are supplied by air and water. Plants must obtain the other 13 elements from the soil or from amendments added to the soil (fertilizers or recycled water).

6.7.1.1 Macronutrients

Plants need relatively large amounts of nitrogen, phosphorus, and potassium. These nutrients are the ones most frequently supplied to plants by fertilizers. Calcium, magnesium, and sulfur are required in somewhat smaller amounts. These six elements, along with carbon, hydrogen, and oxygen, are considered macronutrients.

6.7.1.2 Micronutrients

In contrast to these macronutrients, the *micronutrients* consist of eight essential elements: boron, copper, chlorine, iron, manganese, molybdenum, nickel, and zinc. These elements occur in very small amounts in both soils and plants, but their role is equally as important as the macronutrients. A deficiency of one or more of the micronutrients can result in severe reductions in growth, yield, and crop quality.

Some soils do not contain sufficient amounts of these nutrients to meet the plant's requirements for rapid growth and good production. In such cases, supplemental micronutrient applications in the form of commercial fertilizers or foliar sprays must be made. Table 6-2 lists the 16 essential macronutrients and micronutrients required for plant growth.

6.7.1.3 Heavy Metals

While the use of the term *micronutrient* has been common in agricultural circles for some time, the use of the term *heavy metal* is becoming more common because of environmental concerns. Heavy metals are a group of elements that are associated with industrial and municipal wastewater residuals. At certain levels or concentrations, these elements pose toxicity problems to plants and animals. Included in this group are eight metals: cadmium, chromium, copper, lead, mercury, molybdenum, nickel, and zinc.

In addition to these metals, two nonmetals, arsenic and selenium, are also included in EPA's pollutant concentration list. These two elements are often inaccurately included or referred to as heavy metals.

Heavy metals contain three micronutrients: copper, molybdenum, and zinc, all of which are required for plant growth. It may seem like a contradiction for an element to be an essential nutrient on the one hand, and a toxic or a pollutant on the other, but although low concentrations of these elements are required for growth, at higher levels they can become toxic. It is important for WWLA operators to understand this difference to prevent too much of a good thing from becoming a problem.

Table 6-2. Essential macronutrients and micronutrients.

Nutrients	Chemical Symbol	Type	Source
Carbon	C	Macronutrient	Air and water
Hydrogen	H	Macronutrient	Air and water
Oxygen	O	Macronutrient	Air and water
Nitrogen	N	Macronutrient	Soil and amendments
Phosphorus	P	Macronutrient	Soil and amendments
Potassium	K	Macronutrient	Soil and amendments
Calcium	Ca	Macronutrient	Soil and amendments
Magnesium	Mg	Macronutrient	Soil and amendments
Sulfur	S	Macronutrient	Soil and amendments
Iron	Fe	Micronutrient	Soil and amendments
Manganese	Mn	Micronutrient	Soil and amendments
Boron	B	Micronutrient	Soil and amendments
Molybdenum	Mo	Micronutrient	Soil and amendments
Copper	Cu	Micronutrient	Soil and amendments
Zinc	Zn	Micronutrient	Soil and amendments
Chlorine	Cl	Micronutrient	Soil and amendments

6.7.2 Nutrient Availability and Nutrient Management

All essential nutrients must be available continuously, and in balanced proportions, to support photosynthesis and other metabolic processes of plants. If any one of these essential elements is missing, plant productivity will be limited, or the plant may cease to grow entirely. The principle of *limiting factors*, which states that the level of production can be no greater than that allowed by the most limiting of the essential plant growth factors, applies in both cropping systems and in natural ecosystems.

Although the soil contains large amounts of nutrients, only a very small percentage of these amounts exist in chemical forms that are available to plants. Nutrients can exist in several forms in the soil. When they occur in organic form or as part of an insoluble compound, nutrients are not available to plants (Figure 6-13).

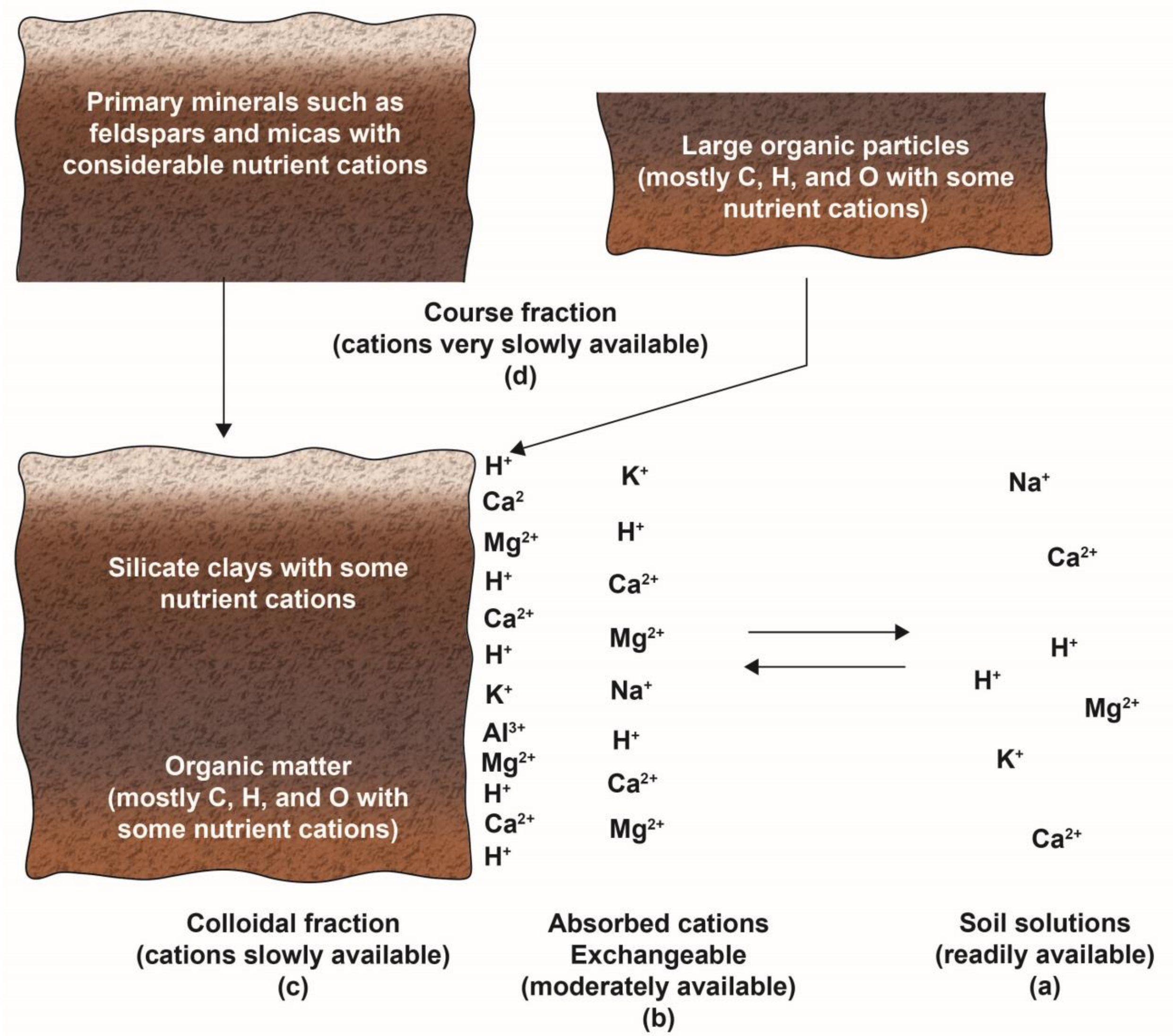

Figure 6-13. Illustration of relationship among soil components that provide nutrient cations for plants. (a) Soil solution nutrients, readily available to plant roots. (b) Adsorbed cations exchangeable with those in soil solution, moderately available. (c) Cations in structural framework of clays and organic colloids can move in time to the adsorbed state, slowly available. (d) Cations in rigid structural framework of minerals and organic tissue released only on weathering or decomposition, at best very slowly available. Most nutrient cations are in component (d). The least are in component (a) (modified from Brady 1990).

Generally, plants can only absorb nutrients when they are in the form of an ion (section 6.3.2 for the definition of *ion*). For example, soil nitrogen occurs in organic and inorganic forms, in solution and as a gas, and as the cation ammonium (NH_4^+) and the anion nitrate (NO_3^-). Plant roots absorb only ammonium and nitrate forms of nitrogen.

Plant-available forms of potassium, calcium, magnesium, manganese, zinc, iron, and copper occur as cations. Potassium and ammonium both have a single positive charge, while the remaining cations have two or more positive charges. In general, these positively charged nutrients are adsorbed onto soil colloids and are not subject to leaching under normal conditions. The higher the charge of a cation, the more strongly it is attracted to the negative charge sites of the soil. However, when the sum of the positively charged nutrients exceeds the soil's capacity to hold nutrients, these nutrients may be lost through leaching.

One form of plant-available nitrogen is nitrate (NO_3^-). The plant-available form of chlorine is the anion chloride (Cl^-). Both of these anions are repelled by the negative charges of soil colloids. Therefore, they are readily leached when water passes through the soil. The plant-available forms of sulfur (sulfate [SO_4^{2-}]) and molybdenum (molybdate [MoO_4^{2-}]) have two negative charges and are also repelled by negatively charged soil colloids. However, these anions may react weakly with positively charged sites, such as occur on iron oxides. Although these elements are not strongly bound to soil colloids under normal conditions, they do not leach as readily as nitrate and chloride and are frequently observed to increase in subsoil horizons having higher clay content and lower pH.

Plant-available phosphorus occurs as an anion with either one or two negative charges, depending on soil pH. Although other anions normally leach readily, phosphorus does not. Phosphorus reacts very strongly with iron, aluminum, and calcium in soil solution, with soil solids such as iron oxides, iron and aluminum hydroxides, and with lime. The strength of these reactions limits the movement of phosphorus.

Boron occurs as a leachable, uncharged molecule (boric acid, H_3BO_3), which reacts very weakly with soil clays.

The availability of nutrients is influenced by the following factors:

- pH
- Soil texture
- The form of nutrient present in the water
- The amount of nutrient present in the soil and soil-water solution

6.7.2.1 pH

Crop nutrient availability is strongly tied to the pH of the soil solution. Decreasing soil pH directly increases the solubility of manganese, zinc, copper, and iron, thereby increasing the availability of these nutrients. At pH values less than 5.5, toxic levels of manganese, zinc, or aluminum (a non-nutrient element common in soils) may be released. On the other hand, the availability of nitrogen, potassium, calcium, magnesium, and sulfur tends to decrease with decreasing pH.

Phosphorus and boron availability decreases at both very low and very high pH, with maximum availability in the range of pH 5.5 to 7.0. Outside of this pH range, phosphorus and boron tend to form insoluble compounds with other elements, such as aluminum, iron, manganese, and calcium. These reactions bind phosphorus much more strongly than boron, with the result that available boron can be readily leached from soils.

Soil pH can sometimes be altered with amendments. As mentioned previously, two widely used soil amendments are lime used to raise the pH and elemental sulfur used to lower the pH.

Increasing soil pH, however, is sometimes not the primary reason for *liming*. As discussed, aluminum and manganese are toxic to plants at relatively low concentrations in the soil solution.

Low pH may be an indicator that aluminum and manganese toxicity is taking place. Liming decreases the solubility of aluminum, manganese, and iron (as well as zinc and copper), causing them to precipitate as relatively insoluble silicate clays, oxides, and hydroxides. Gypsum is another soil amendment that can be used to reduce aluminum toxicity without raising the pH.

Figure 6-14 shows the relationship between pH and nutrient availability. Typically if adequate phosphorus is provided to the crop system (pH between 5.5 and 7) all other essential nutrients will adequately be provided as seen in Figure 6-14.

If soil pH needs to be raised or lowered, the timing and application rate of soil amendments are critical for healthy crops and a bountiful harvest. The soil class, soil starting pH, soil buffering ability, soil temperature, and soil moisture content have an effect on how much soil amendment is needed and how fast or to what degree the pH will change. Elemental sulfur is especially dependent on temperature and moisture content. Typically sulfur should be applied in spring with soil temperatures above 75ºF and 4–6 weeks should be allowed before the desired pH change is realized. Sulfur should also be well mixed with the soil so that the soil microorganisms can oxidize the sulfur and produce sulfuric acid to acidify the soil. As an example, it is recommended that for each unit drop in pH desired, a well buffered soil (e.g., a silty clay loam with 4% organic matter) will require about 0.5 tons/acre of elemental sulfur (Brady and Weil 2008). Lime can be used as a soil amendment to raise soil pH in acidic soils. These soils are typically not found in southern Idaho but may be found in northern Idaho. The University of Idaho fertilizer guide for alfalfa grown in northern Idaho makes the following recommendation for liming in acidic soils: "If soil pH is between 5.5 and 5.8 apply 1 ton of lime per acre and thoroughly incorporate into the soil prior to seeding alfalfa. If the soil pH is less than 5.4, apply 2 tons of lime per acre and incorporate it into the soil prior to seeding alfalfa." For additional information on lime and liming materials, see University of Idaho CIS 787, *Liming Materials* (Mahler 2005).

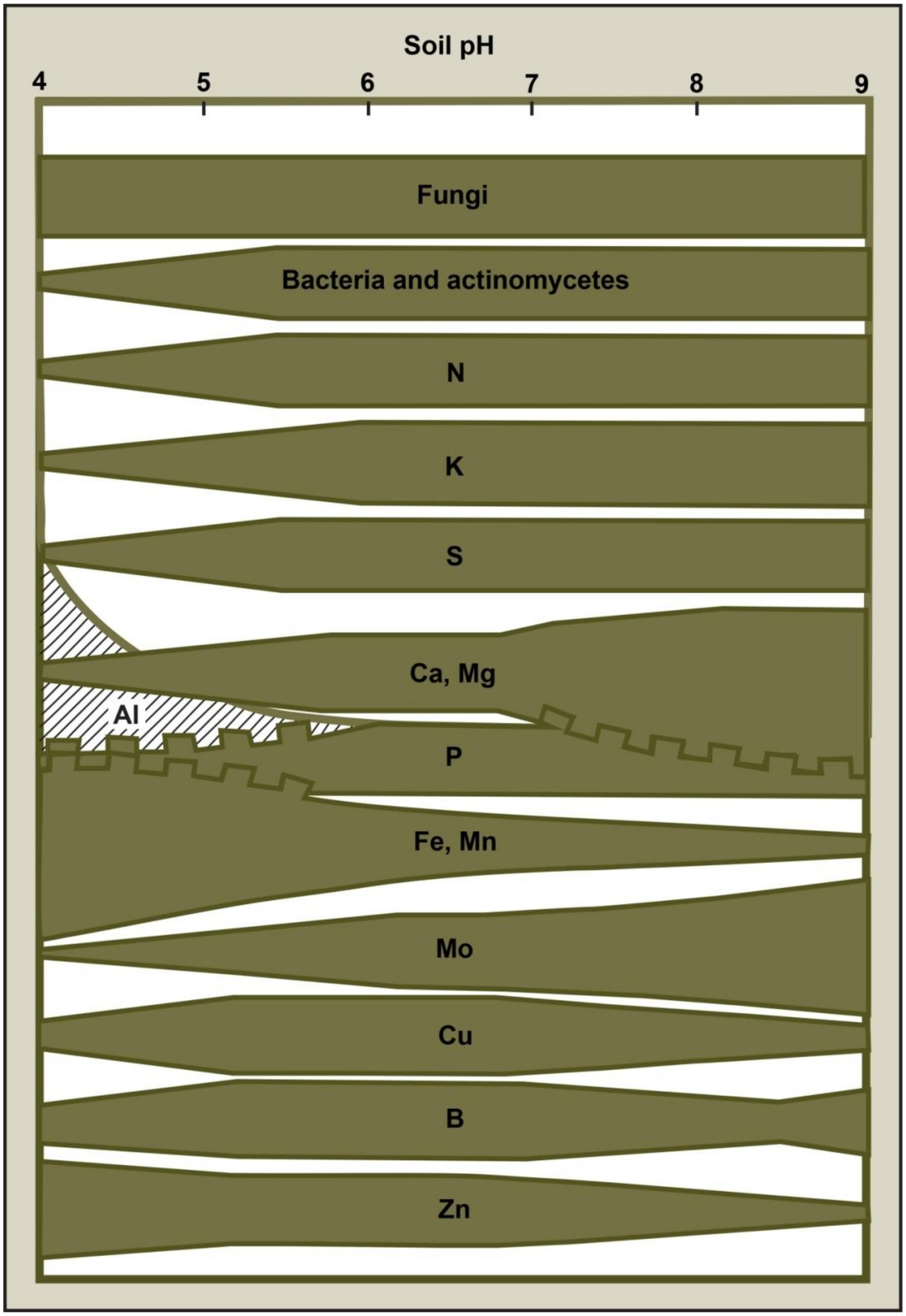

Figure 6-14. Relationships existing in mineral soils between pH and the availability of plant nutrients. The relationship with activity of certain microorganisms is also indicated. The width of the bands indicates the relative microbial activity or nutrient availability. The jagged lines between the P band and the bands for CA, Al, and Fe represent the effect of these metals in restraining the availability of P. When the corrections are considered as a whole, a pH range of about 5.5 to perhaps 7.0 seems to be best to promote the availability of plant nutrients. In short, if the soil pH is suitably adjusted for phosphorus, the other plant nutrients, if present in adequate amounts, will be satisfactorily available in most cases (Brady and Weil 2008).

Depending on the source, lime also supplies significant amounts of calcium and magnesium. Indirect effects of liming include increased availability of phosphorus, molybdenum, and boron, the creation of more favorable conditions for microbiological processes such as nitrogen fixation and nitrification, and, in some cases, improved soil structure. By increasing soil pH, liming also improves the effectiveness of several herbicides.

Since lime applications decrease availability of zinc, iron, manganese, and copper, excessive lime applications can cause deficiencies of these elements. Heavy applications of lime have also caused decreased uptake of boron in some cases.

6.7.2.2 Soil Texture

Not all soils are susceptible to the same nutrient deficiencies. Differences in soil texture will affect a soil's capacity to retain nutrients. Nutrients are more apt to leach through a coarsely textured sandy soil than through a finely textured clayey soil. For example, coarsely textured soils low in organic matter are susceptible to sulfur deficiencies, while sulfur is usually in adequate supply in clayey soils or soils high in organic matter. Table 6-3 shows some soil conditions that can lead to nutrient deficiencies.

Table 6-3. Soil factors that may lead to deficiencies of selected nutrients.

Nutrient	Soil Factors Resulting in Deficiency
Nitrogen and potassium	Excessive leaching on coarse-textured, low organic matter soils
Potassium	Acid, low organic matter soils Cold, wet soils such as occur during early spring Newly cleared soils
Sulfur	Excessive leaching on coarse-textured, low organic matter soils in areas where air pollution is low (minimal levels of SO_4)
Calcium and magnesium	Excessive leaching on coarse-textured, low organic matter soils Soils where large amounts of potassium have been applied
Iron	Poorly drained soils Low organic matter soils, high pH soils (pH > 7.0)
Zinc	Cold, wet soils low in organic matter and highly leached. High pH soils (pH > 7.0) Soils high in phosphorus
Copper	Peat and muck soils High pH, sandy soils
Boron	Excessive leaching on coarse-textured, low organic matter soils Soils with pH > 7.0
Manganese	Excessive leaching on coarse-textured, low organic matter soils Soils with pH > 6.5
Molybdenum	Soils high in iron oxides (high adsorption of molybdenum). Soils cropped for a long time

Note
Soil testing should be done to determine which nutrients are needed and how much of each should be applied. Excessive applications of the following nutrients may lead to toxicity: boron, copper, iron, manganese, and zinc.

6.7.2.3 Nutrients in Water

Another factor that influences the plant availability of nutrients is the form in which a nutrient is present in the water applied to soil. Some nutrients in water are largely present as organic compounds that must be broken down by soil microorganisms before plants can use the nutrients. Other nutrients are present in a water-soluble form that is immediately available for plant uptake.

6.7.2.4 Levels of Nutrient Availability

The following are three levels of nutrient availability (Figure 6-15):

1. Deficient—Marked decreases in relative plant growth (yield) occur with limited amounts, or availability, of the nutrient (i.e., supply of the nutrient is inadequate and is limiting plant growth). An addition of the nutrient will increase yield.
2. Sufficient—The maximum/optimal yield has been reached, and the nutrient is not limiting crop yield, so increasing the supply or availability of the nutrient has no effect on yield.
3. Toxic—Further additions or availability of a nutrient beyond the sufficient range causes marked decreases in yield and, eventually, no growth.

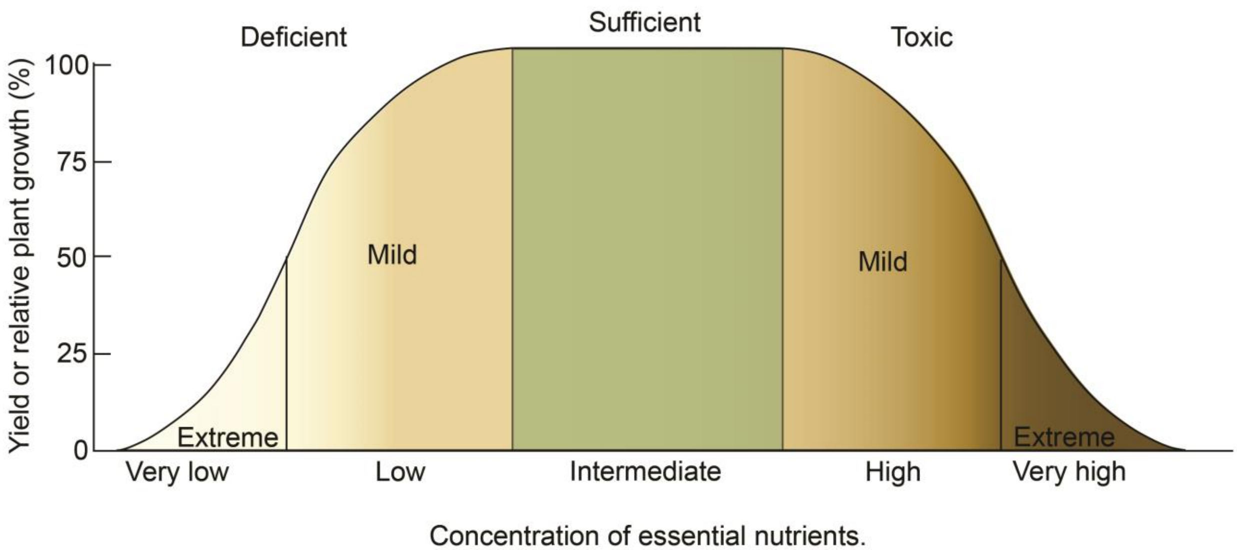

Figure 6-15. Relationship between plant growth and concentration in the soil solution of elements that are essential to plants. Nutrients must be released (or added) to the soil solution in just the right amounts if normal plant growth is to occur (modified from Brady 1990).

Symptoms of nutrient deficiency usually appear on the plant when one or more nutrients are in short supply. In many cases, a deficiency may occur because a nutrient is not in a plant-available form. Symptoms of nutrient deficiency for specific elements are listed in Table 6-4.

Table 6-4. Key to nutrient disorders.

Nutrient	Symptoms of Nutrient Deficiency
Nitrogen	General chlorosis (yellowing). Chlorosis progresses from light green to yellow. Entire plant becomes yellow under prolonged stress. Growth is immediately restricted and plants soon become spindly and drop older leaves.
Phosphorus	Leaves appear dull, dark green, blue green, or red-purple, especially on the underside, and especially at the midrib and vein. Petioles (the stalk that attaches the leaf to the stem) may also exhibit purpling. Restriction in growth may be noticed.
Potassium	Leaf margins tanned, scorched, or have necrotic (dead) spots (may be small black spots, which later coalesce). Margins become brown and cup downward. Growth is restricted and death (*die back*) may occur. Mild symptoms appear first on recently matured leaves, then become pronounced on older leaves, and finally, on younger leaves. Symptoms may be more common late in the growing season due to translocation of potassium to developing storage organs.
Calcium	Growing points usually damaged or dead (die back). Margins of leaves developing from the growing point are first to turn brown.
Magnesium	Marginal chlorosis or chlorotic blotches, which later merge. Leaves show yellow chlorotic interveinal tissue on some species, reddish purple progressing to necrosis on others. Younger leaves affected with continued stress. Chlorotic areas may become necrotic, brittle, and curl upward. Symptoms usually occur late in the growing season.
Sulfur	Leaves uniformly light green, followed by yellowing and poor, spindly growth. Uniform chlorosis does not occur.
Copper	Leaves wilt, become chlorotic, then necrotic. Wilting and necrosis are not dominant symptoms.
Iron	Distinct yellow or white areas appear between veins, and veins eventually become chlorotic. Symptoms are rare on mature leaves.
Manganese	Chlorosis is less marked near veins. Some mottling occurs in interveinal areas. Chlorotic areas eventually become brown, transparent, or necrotic. Symptoms may appear later on older leaves.
Zinc	Leaves may be abnormally small and necrotic. Internodes are shortened.
Boron	Young, expanding leaves may be necrotic or distorted followed by death of growing points. Internodes may be short, especially at shoot terminals. Stems may be rough, cracked, or split along the vascular bundles.

6.7.2.5 Nutrient Management

When plant nutrients are applied to soils as recycled water, animal manure, or commercial fertilizers, five things can happen to these nutrients:

1. Plants grown on the site can use the nutrient.
2. The nutrient can stay in the soil.
3. Some nutrients can be lost, as water washes them down through the soil profile in a process called leaching.
4. If fertilizers or wastes are left on the soil surface, runoff water may carry nutrients away in solution or as part of eroded sediments.
5. Some nutrients can be lost as a gas to the air (through volatilization or denitrification).

To maximize nutrient use, the WWLA operator should develop a *nutrient management plan*. Developing such a plan requires information on the *amount* of nutrients that can be applied to meet the agronomic need of the crop or vegetation grown, the *form* or source of nutrients, the *placement* of nutrients on the field, and the *timing* of nutrient applications. Nutrients can be managed by adjusting these four components.

The term *agronomic rate* means that nutrients will be applied in accordance with the needs of the crop or vegetation. Thus, rates and timing of application must be adjusted to optimize plant response to the applied nutrients. When this occurs, the plant's ability to use the nutrients is maximized, so fewer nutrients can escape into the environment. Efficient nutrient management is a goal for all systems, whether they are growing trees or vegetables, or managing pasture at a land application site.

6.8 Crop Nutrient Requirements

WWLA operators must understand nutrient requirements and growth cycles of the plants being grown. Crops vary in their ability to use nutrients (crop uptake). Bermuda grass has very high nutrient requirements, whereas a mature forest has much lower requirements.

DEQ defines *typical crop uptake* as the median constituent crop uptake from the 3 most recent years the crop has been grown. For crops having less than 3 years of actual crop uptake data, other crop yield data or nutrient content values may only be used if approved in writing by DEQ in advance of use. If written approval is not provided by DEQ, compliance with the permit nitrogen loading limit shall be determined by comparing the current year nitrogen loading to the current year nitrogen uptake.

Domestic wastewater generally contains low concentrations of the major plant nutrients. In such cases, it is possible that plant nutrients such as nitrogen, phosphorus, and potassium may have to be added as supplemental fertilizers, manures, compost, or soil amendments to get expected crop yields (optimum crop growth). Insufficient nutrients may result in reduced crop yield and reduced nutrient uptake efficiencies. The addition of supplemental nutrients should be based on soil test recommendations and expected crop yields. WWLA operators are encouraged to consult DEQ, the local Cooperative Extension Service, NRCS, or agricultural consultants for assistance in interpreting soil test results, determining potential supplemental fertilization rates, and developing nutrient management plans. Any supplemental source of nutrients will have to be documented and reported as part of the reuse permit requirements.

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7 Ground Water and Hydrology

Need-to-Know Criteria
Hydrologic cycle and land application
Evapotranspiration
Runoff to surface waters, surface water pollution, and ponding
Soil water and water table depths
Monitoring wells and well construction

To determine if a land application treatment system is functioning properly, the WWLA operator needs a basic understanding of ground water and hydrology. *Hydrology* is simply the study of water as it occurs on and below the surface of the earth as well as in the atmosphere. The movement of water on the land, in the ground, and through the air is termed the *hydrologic cycle*.

7.1 Hydrologic Cycle

The hydrologic cycle is the continuous process of water leaving the earth's surface and eventually returning in the form of precipitation (Figure 7-1). Water falling from the atmosphere as rain or snow can do one of three things:

1. Evaporate and return to the atmosphere.
2. Run off to streams, rivers, lakes, and oceans.
3. Infiltrate into the soil.

Land-applied recycled water acts in much the same way as natural precipitation and becomes a part of the hydrologic cycle. In a properly operated land application system, however, recycled water should either evaporate or infiltrate into the soil.

Runoff from land application is not acceptable. Percolation of untreated or partially treated recycled water below the root zone is also undesirable. Therefore, one of the most important goals for the WWLA operator is to apply recycled water at rates that will not only supply the nutrient needs of crops or vegetative covers but that will not exceed the rate at which the soil-crop system will accept, hold, and use the water. WWLA operators should understand that if not properly managed, recycled water can pond on the soil surface, percolate to deeper ground water, or flow laterally as ground water until it reaches a surface water body (surface water and ground water interconnection).

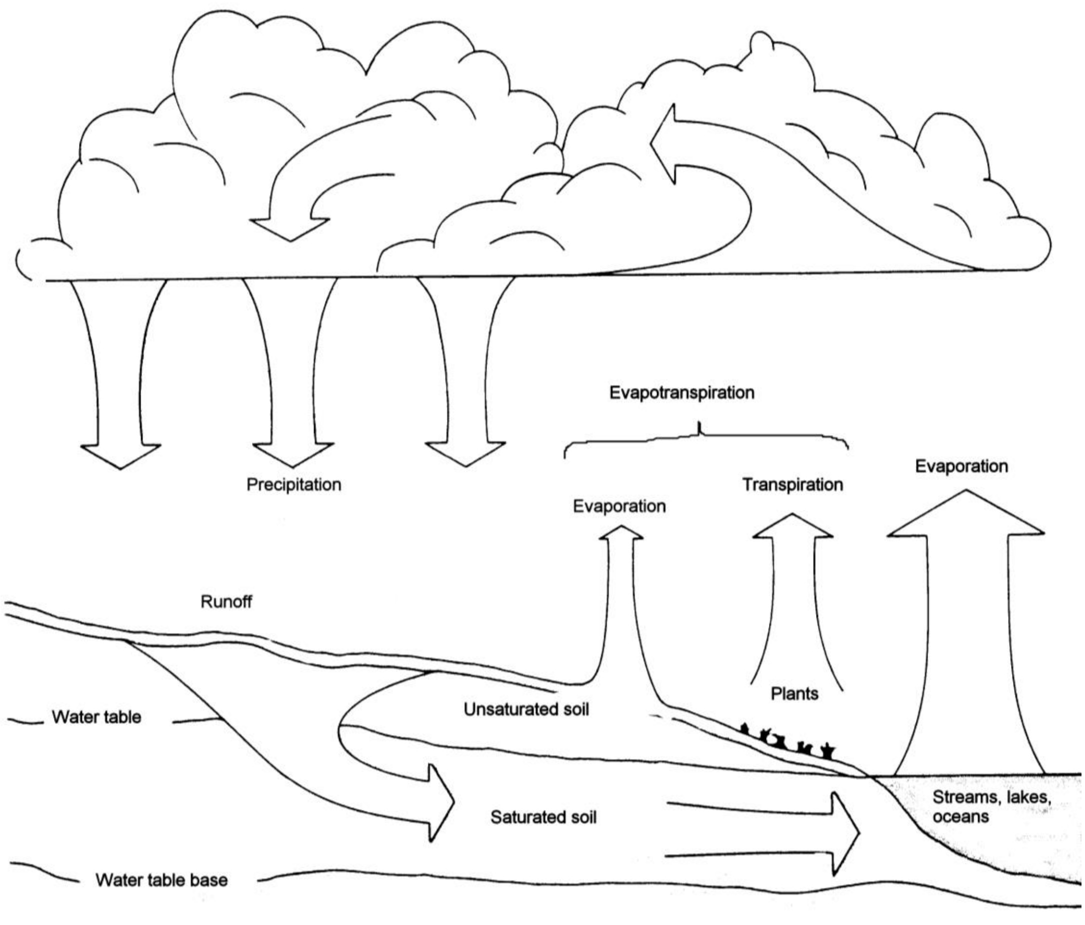


Figure 7-1. The hydrologic cycle (Brady 1990).

7.2 Evaporation and Evapotranspiration

Water can evaporate in several ways, and water in the form of precipitation, irrigation, and recycled water needs to be considered at a land application site. When the humidity is low, water may evaporate before it even reaches the ground. More importantly, for the purposes of land application, water can also evaporate from the soil surface and from leaf surfaces.

Transpiration is the process of evaporation at leaf surfaces when water moves upward and through a plant. The combined loss of water to the atmosphere by evaporation from the soil surface (E) and by transpiration (T) is called *evapotranspiration* (ET) (Figure 7-2).

ET is responsible for most of the water removal from soils during a crop's growing season. ET rates are influenced by the following factors:

- Sunlight—Solar radiation provides the energy necessary for evaporation to take place; ET is higher on a bright sunny day than on a cloudy day.

- Atmospheric vapor pressure—Evaporation occurs when the atmospheric vapor pressure is low compared to the vapor pressure at the soil and leaf surfaces; ET is higher in arid climates than in humid regions.
- Temperature—A change in temperature has a much greater effect on the vapor pressure at soil and leaf surface than on the atmospheric vapor pressure; ET increases with an increase in temperature.
- Wind—The movement of air sweeps away vapor moisture from wet surfaces; high winds will increase ET.
- Soil moisture content—Water must be present for evaporation to occur; ET is higher for moist soils compared to soils with a low moisture content.

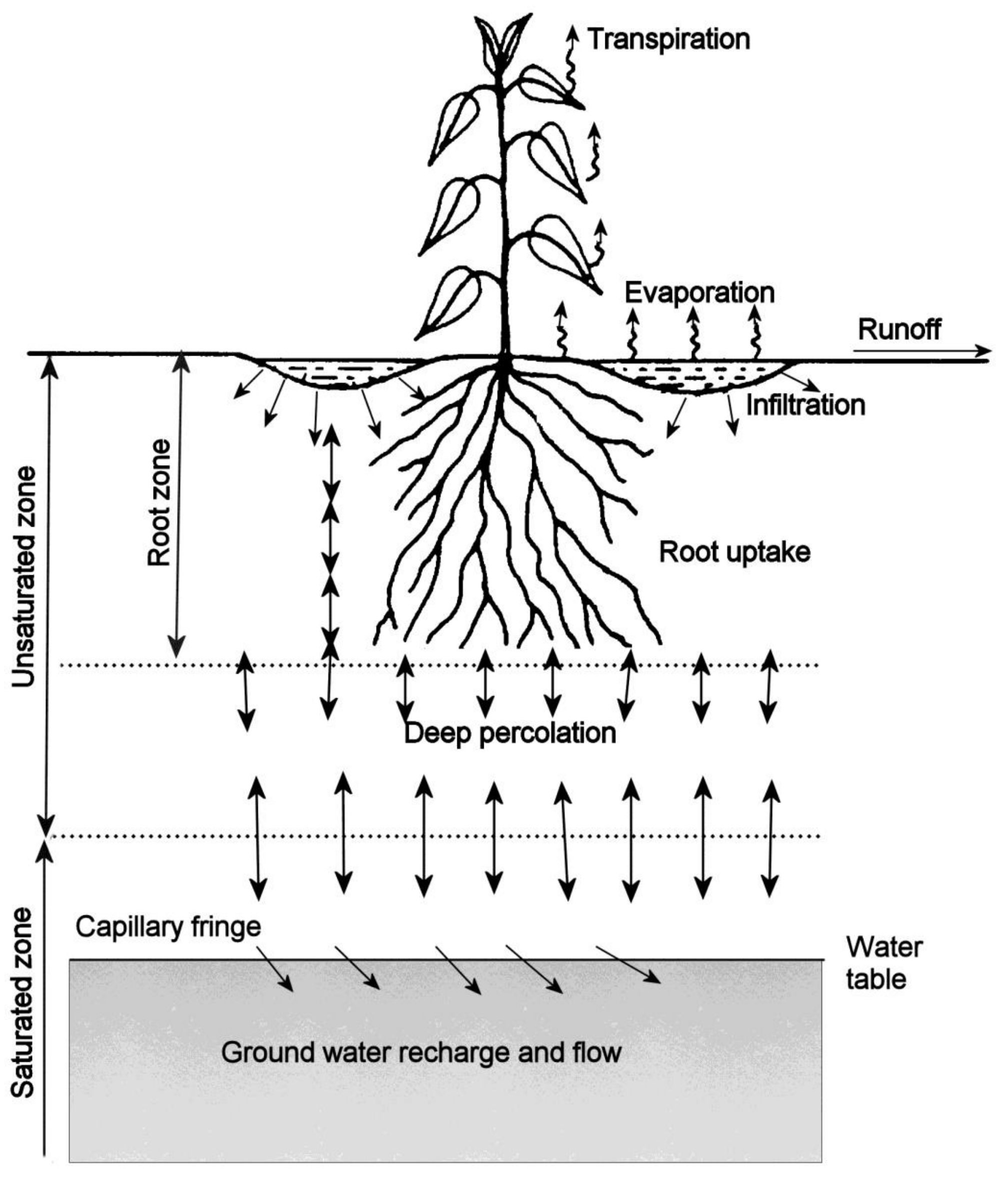


Figure 7-2. The water balance of a root zone (Hillel 1980).

After ET occurs, water vapor in the atmosphere condenses into clouds. Eventually precipitation falls in the form of rain or snow and the cycle begins again.

7.3 Runoff to Surface Waters

Water that does not evaporate to the atmosphere or infiltrate into the soil can accumulate and pond in the field and if sufficient slope is present, the excess water may run off the field. Runoff travels over the soil surface and may transport soil particles and nutrients from the field to nearby surface water if present (i.e., streams, rivers, lakes, and oceans). Factors affecting runoff are the same as those affecting infiltration (section 6.4.2):

- Soil texture
- Soil structure
- Soil moisture
- Vegetative cover
- Topography and landscape position

Runoff can negatively impact both soil and water quality. These negative impacts include soil erosion and surface water pollution. Nutrients contained in the runoff, especially phosphorus, have the potential for causing surface water quality impacts.

7.3.1 Soil Erosion

When runoff occurs, it carries suspended soil particles. This loss or movement of soil is called *soil erosion.* Around 5 billion metric tons of soil is moved annually in the United States, some two-thirds is moved by water (the remainder is moved by wind).

Unfortunately, much of this eroded soil ends up in surface waters. Sediment carried by runoff clogs streams, fills lakes, and often carries nutrients and pollutants to these waters. It can reduce the capacity of water storage reservoirs, require dredging of rivers and streams, and can impact both water and wastewater treatment plants by increased sediment loads.

Runoff high in sediment can cause *turbidity*, which can smother aquatic life and shade out desirable aquatic vegetation. Sediment also may carry pesticides—such as herbicides and insecticides—that may be toxic to aquatic plants and animals. The varying chemical properties of pesticides—for example, their solubility, toxicity, and chemical breakdown rate—determine the potential damage to water quality.

Reducing soil erosion is the key to reducing the damaging effects of sedimentation. Fortunately, with current technology and management practices, erosion can be reduced to acceptable levels. The challenge is to match the appropriate technology to each situation.

7.3.2 Surface Water Pollution

In addition to soil particles, runoff can carry with it other constituents that affect water quality. Bacteria, viruses, organics, and a variety of other chemicals may impact plant and animal life in surface waters. These pollutants also have the potential to impact humans who use these surface waters for fishing, recreation, or drinking water.

Nutrients carried by runoff to surface waters can also result in accelerated *eutrophication*. Natural eutrophication is the slow nutrient enrichment of streams and lakes and is responsible for the *aging* of ponds, lakes, and reservoirs.

Rapid eutrophication is usually associated with increased algae growth or *blooms*. In freshwater ecosystems developed under very low phosphorus conditions, large additions of nutrients, especially phosphorus, can stimulate the production of these algae blooms. As the algae die, organisms in the aquatic system decompose the algae to use as a food source. In the process, they also use significant amounts of oxygen. As more and more algae grow and then decompose, dissolved oxygen levels are depleted. This condition can result in fish kills, offensive odors, unsightliness, and reduced attractiveness of the water for recreation and other public uses.

7.3.3 Ponding

If the topography of a land application site includes low-lying areas, runoff may collect in these areas and create *ponding*. Ponding can also occur in the field at the original point of application. Ponding can cause hydraulic overloading and result in ground water contamination by leaching water past the crop root zone. In addition, land application sites should be managed to prevent water from ponding to the point where the ponded water *putrefies* (decomposition of waste elements in the water), which may cause odors or supports *vectors (*such as birds, flies mosquitoes, or rats) that may transmit disease.

7.4 Infiltration into the Soil

As discussed in the following sections, factors important to soil infiltration include soil water, water table depths, artificial affects to site hydrology, and ground water monitoring wells.

7.4.1 Soil Water

Water that does not evaporate or move as surface runoff, infiltrates into the soil, and percolates downward. As discussed in section 7.2, some of this water is used by plants and is removed from the soil environment by ET. The remaining water flows through the unsaturated portion of the soil (*unsaturated zone*) and below the root zone until it reaches the *saturated zone* (Figure 7-3). This is the zone in which all of the pores in the soil or bedrock are filled with water. The surface or uppermost level of the saturated zone is called the *water table*. When water percolating through the soil reaches the water table, it becomes *ground water*. Ground water is any water contained in interconnected pores located below the water table.

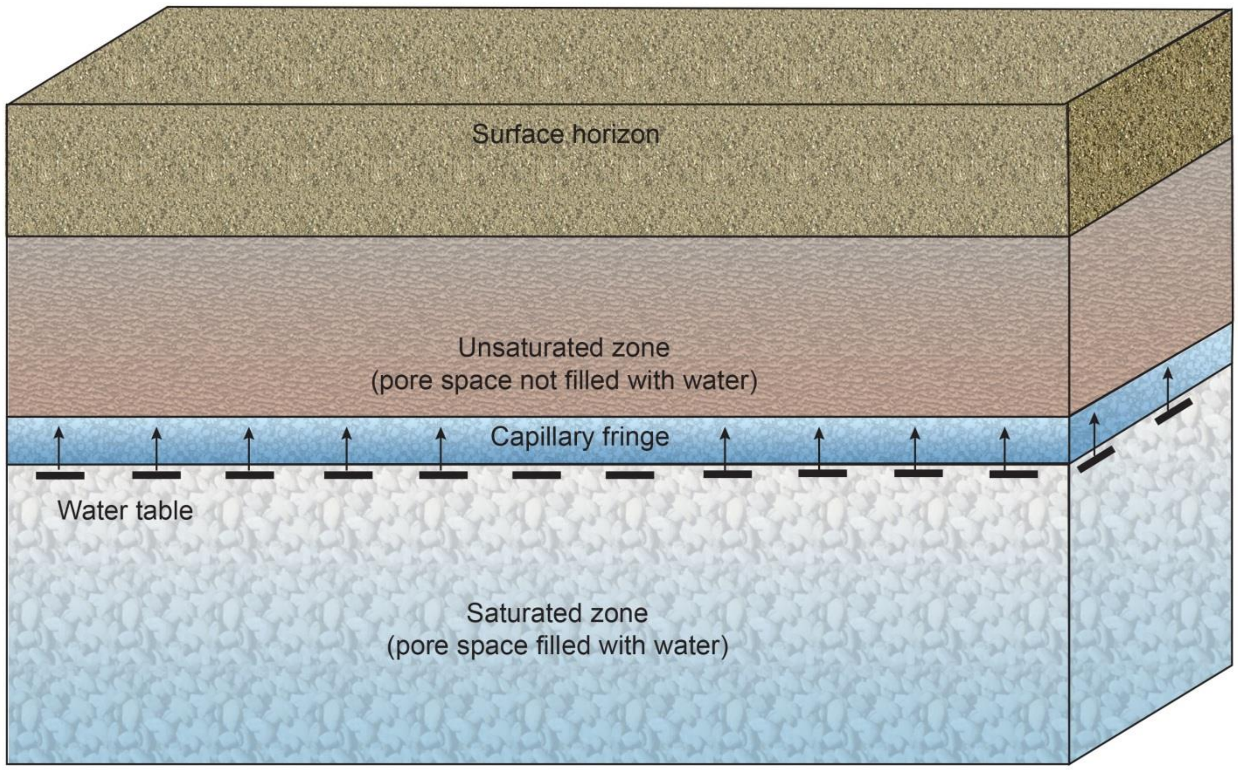


Figure 7-3. Divisions of soil water.

Although ground water is thought to occur in large underground lakes or streams, it does not. Instead, it occupies spaces within rock fractures or between particles of sand, gravel, silt, or clay and flows through underground formations called *aquifers*. An aquifer is the rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Ground water does not move rapidly in an aquifer. It may move only a few feet per month or even per year, whereas surface streams flow several feet per second.

Although the unsaturated zone and saturated zone appear to be distinct and separate areas, it is important to remember that they are part of a continuous flow system. It is sometimes difficult to determine exactly where one ends and the other begins.

Ground water often rises into the soil immediately above the water table by a process known as *capillary action* (the physical attraction of water to soil or rock particles). This area, where water from the saturated zone is pulled up into the unsaturated zone by capillary action, is called the *capillary fringe*.

The height of the capillary fringe is determined by the texture of the soil. In finely textured soils, the capillary fringe may be several inches high; in coarsely textured soils it may be insignificant. Although some debate exists about whether the capillary fringe is part of the unsaturated or the saturated zone, for the purposes of this manual, the capillary fringe is considered part of the saturated zone.

7.4.2 Water Table Depths

Water table depths vary across the landscape and are determined by the confining layers present below the soil surface. These confining layers have little to no permeability and, therefore, restrict water movement. These layers may be very deep and cover a large area, such as a bedrock layer.

A water table that results from a confining layer is called an *apparent* or *permanent* water table. Water table depths can be determined by measuring the depth to free water in a shallow, unlined auger hole.

A water table may also be caused by a shallow restrictive horizon in the soil that creates saturated conditions above it, while unsaturated conditions exist below it. This type of water table is called a perched water table, and usually occurs over a small area (Figure 7-4). Perched water table depths are quite variable and are usually of shorter duration than an apparent water table.

Water table depths also move up and down in response to precipitation, ET patterns, and irrigation canals. The unsaturated zone can become saturated during periods of excessive precipitation. Saturated conditions in the unsaturated zone, however, are temporary and are usually seasonal (Figure 7-5).

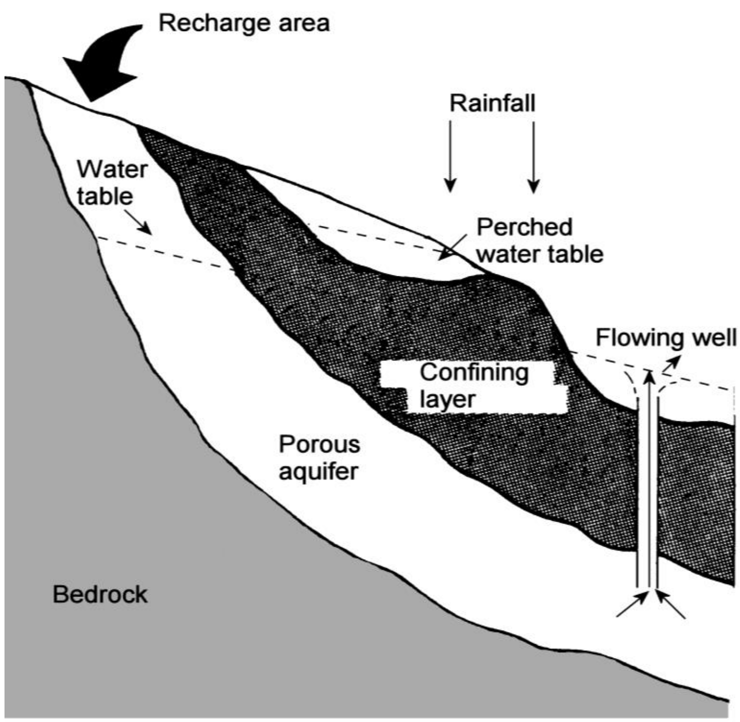


Figure 7-4. Porous aquifer and perched water table above an impermeable layer (Brooks et al. 2003).

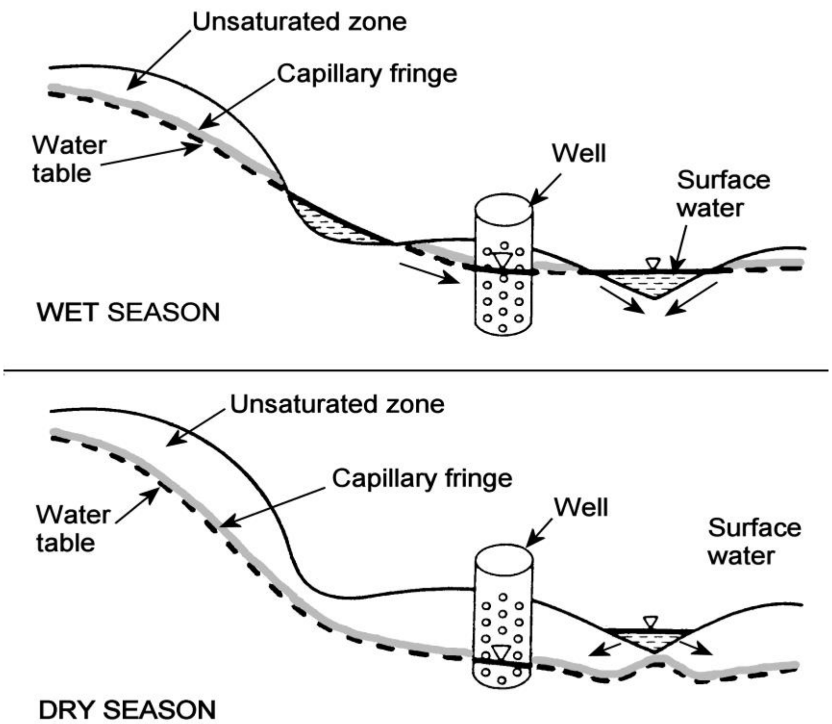


Figure 7-5. Ground water characteristics and water table changes from wet to dry season (Brooks et al. 2003).

The goal of a land application system is to use the rooting zone of the soil, in conjunction with a suitable vegetative cover, to adequately treat water before it reaches the saturated zone (i.e., ground water). These systems are designed to operate in aerobic environments. Therefore, depth to the water table is important because it determines both the volume of unsaturated soil through which constituents must travel before reaching ground water and the amount of time that constituents are in contact with unsaturated soil. The potential for ground water contamination increases where the soils are thin and the underlying bedrock or confining layer is permeable, or where the water table is near the soil surface. Such sites would not be considered suitable for land application. Generally, at least 3 feet of unsaturated soil are needed for adequate treatment.

Even when the water table is sufficiently deep, the potential for ground water contamination exists. Overapplication of water (hydraulic overloading) can alter the hydrology of a site and create saturated conditions in what would normally be the unsaturated zone. Gravel and fractured bedrock—and improperly constructed monitoring wells—can create a direct conduit to ground water leading to ground water contamination. Overapplication of recycled water (hydraulic overloading), fertilizers, or soil amendments can result in leaching nitrates and other pollutants into the ground water.

Overapplication of water can also cause the water table to rise closer to the soil surface, creating a localized rise in the water table called *ground water mounding*, which is defined as a localized rise in the water table, during land application, caused by a subsurface confining layer (Figure 7-6). This situation, if close enough to the soil surface, is undesirable; it can cause anaerobic conditions in the root zone and limit the growth potential of the vegetative cover; and it can also result in poor treatment of the recycled water. Ground water tables may fluctuate seasonally and create conditions such as lowered water tables and ground water mounding.

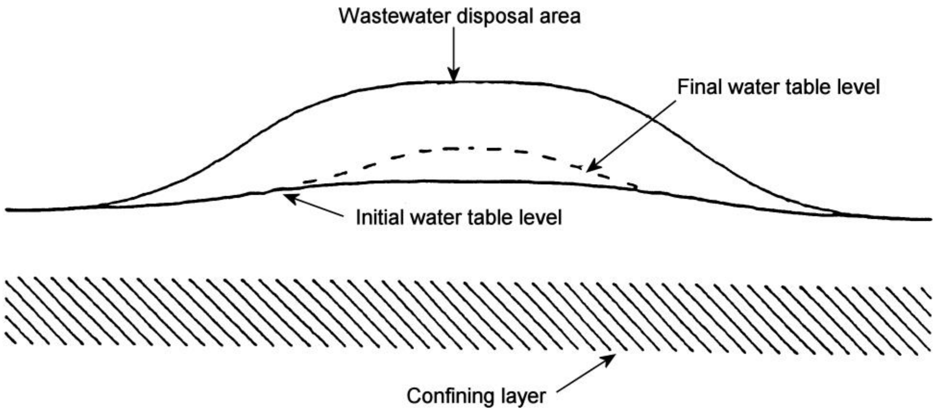


Figure 7-6. Ground water mounding under treatment system (Soil Science Society of North Carolina 1989).

7.4.3 Artificially Affecting Site Hydrology

Pumping water from a well can also alter the natural hydrology of a site. It is important to understand that pumping water from a well can change the natural flow of ground water in its vicinity. The net result can be a complete reversal of the natural direction of ground water flow. Thus, a downgradient contaminant may actually be drawn against the natural flow into an upgradient well. The possible range of such an effect depends on the rate of pumping and the ability of water to move within the aquifer.

Artificial surface (such as from recycled water) and subsurface drainage can also affect ground water levels. Surface drainage is sometimes used where upslope runoff may impact a site. Surface water is diverted by means of dikes or berms that carry surface water runoff safely away from a treatment site. Installation of any surface drainage structures at a land application site requires approval by the DEQ regional office.

Subsurface drainage is often used in agricultural settings. Ditches or porous pipes withdraw water from the soil and carry it to an off-site waterway, such as a road ditch or stream. Fields with shallow ground water conditions or fields that require tiling and drainage to remove shallow ground water are generally not acceptable water reuse sites.

7.5 Ground Water Monitoring Wells

Many land application sites maintain a system of monitoring wells to assess how land application practices are impacting ground water. Ground water monitoring often plays a major role in evaluating and modifying management and loading practices to protect and maintain ground water quality. The location and optimum number of monitoring wells depends on site-specific characteristics, such as the number of land application fields, hydraulic and constituent application rates, location of wastewater and recycled water lagoons/ponds, size (acreage) of the fields, ground water depth, ground water flow characteristics, ground water uses, and the purpose of the monitoring system.

7.5.1.1 Well Location

The location of ground water monitoring wells is important in evaluating the change in ground water quality as it progresses through the land application site, and it allows the operator to see how the land application activities affect ground water quality. Upgradient monitoring wells indicate the existing ground water quality, and downgradient wells indicate the effect the land application site has on ground water quality.

To achieve their intended purpose, monitoring wells must be located along the path of ground water flowing underneath the land application site. Typically, at least one well is installed hydraulically *upgradient* and at least two wells are installed hydraulically *downgradient* of the land application site, as shown in Figure 7-7. The number of ground water monitoring wells would be based on various factors such as the size of the reuse fields, depth and beneficial uses of the aquifer, and proximity of ground water users and is specified in the permit.

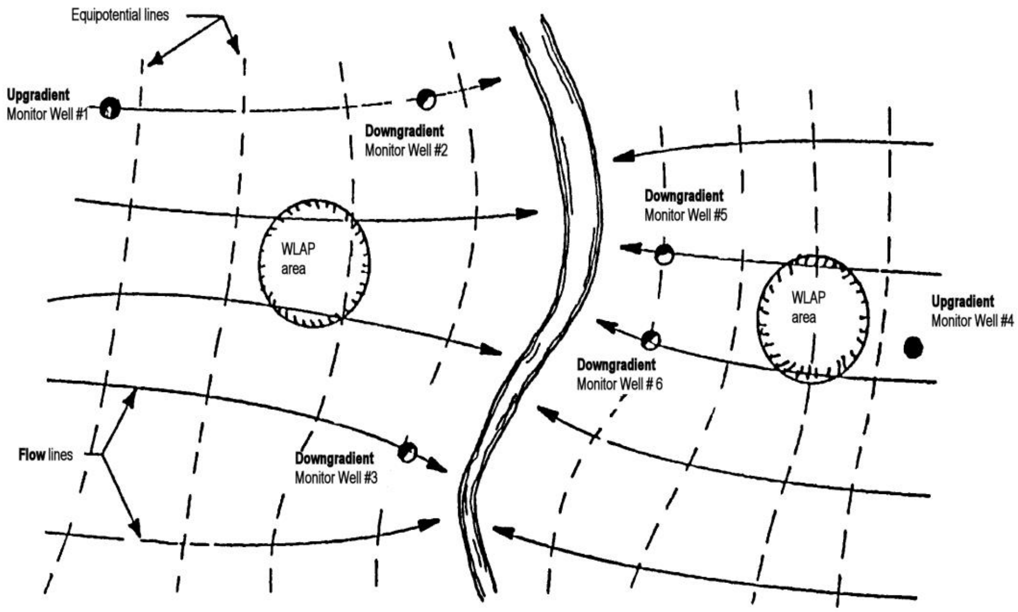


Figure 7-7. Proper and improper locations for ground water monitoring wells (wells 1, 2, and 3 are improperly located; wells 4, 5, and 6 are properly located).

Analyses of ground water sampled from the upgradient well establishes the quality of ground water unimpacted by the land application site (i.e., background quality), while ground water samples from the downgradient well establish (by comparison with upgradient samples) the impact of land application operations on ground water quality to determine compliance with "Ground Water Quality Rule" (IDAPA 58.01.11).

7.5.1.2 Well Construction

Need-to-Know Criteria
Along with proper location, proper well construction is critical to a valid and acceptable ground water monitoring network. The construction requirements are presented in the reuse guidance at *www.deq.idaho.gov/guidance-documents*. Important requirements are discussed below.

The well casing and screen must be made of materials compatible with the constituents of the wastewater being monitored. Polyvinyl chloride (PVC) is generally a good choice because of its ease of handling and low cost. However, the pieces of casing and screen must be joined using threaded couplings. Glues of any sort cannot be used, since volatile/semivolatile elements in glues may leach into the ground water. PVC is recommended for inorganic samples only.

The length and positioning of the well screen below land surface must be such that the static water table is never above the uppermost or below the lowermost screen openings at any time of the year (Figure 7-8). Screen settings that do not meet this criteria result in either *dry* wells (i.e., the water table is below the screen, precluding collection of a sample) or a situation where the layer of dissolved contaminants in the ground water may be above the zone where the sample is collected (i.e., the water table is above the uppermost screen openings).

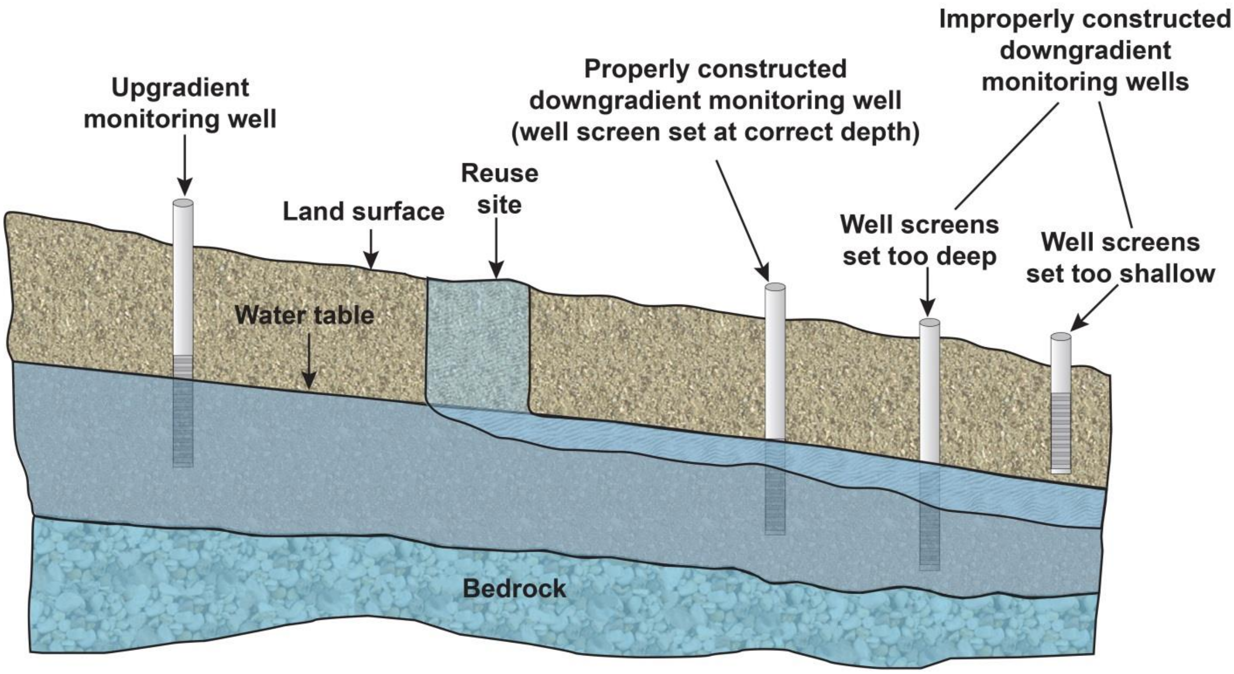
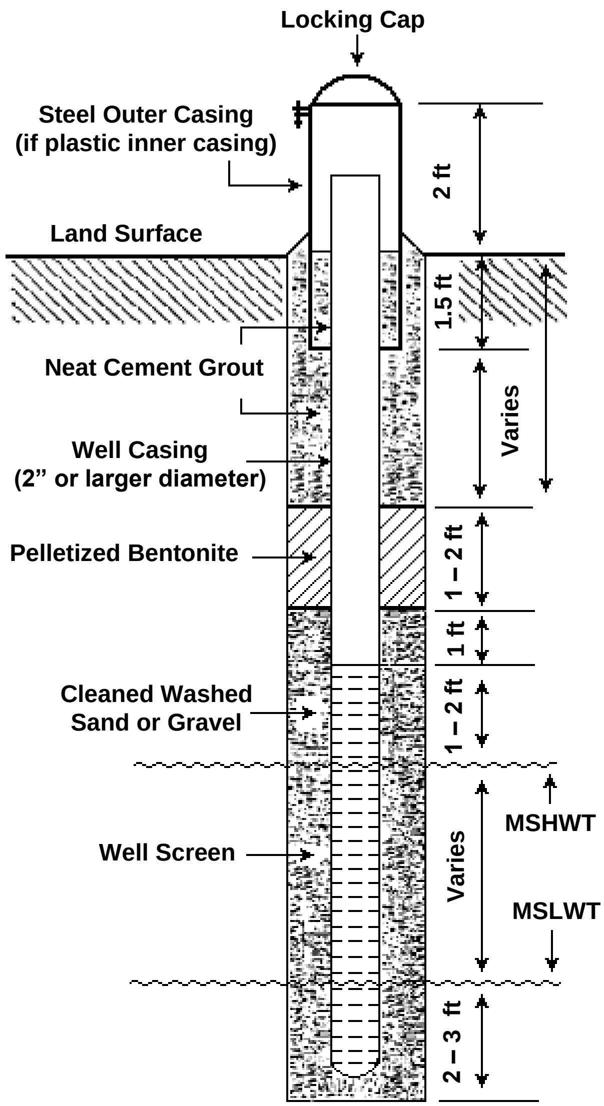


Figure 7-8. Proper and improper placement of screens for monitoring wells.

The well casing must be grouted from the land surface to a depth of no more than 3 feet above the top of the well screen. Because of shrinkage when dry, bentonite grouts may not be used, except as a plug to keep cement grout away from the well screen (Figure 7-9).



1. Borehole to be at least 4 inches larger than outside diameter of casing.

2. Casing and screen to be centered in borehole.

3. Top of well screen should extend from approx. 1 – 2 feet above MSHWT down to 2 – 3 feet below MSLWT.

4. Casing and screen material to be compatible with type of contaminant being monitored.

5. Well head to be labeled with visible warning saying: “Well for monitoring and not considered safe for drinking”.

6. Well to be afforded reasonable protection against damage after construction.

Note:

MSHWT = Mean Seasonal High Water Table

MSLWT = Mean Seasonal Low Water Table

Figure 7-9. Construction details for ground water monitoring well.

A permanent, easily visible label or tag must be attached to each well, denoting that the well is for monitoring and water from the well should not be used for drinking. A permanent label should contain details about the construction of the well (e.g., date installed, installer, and depth).

The well must have a watertight lockable cap to prevent unauthorized access. Appendix B provides guidance for monitoring well construction.

7.5.1.3 Baseline Well Characteristics

Background conditions of monitoring data determine the baseline well characteristics. Because the purpose of installing monitoring wells is to determine the condition of ground water based on the analyses of ground water samples, it is essential that good quality samples be obtained. Prior to accepting a newly installed monitoring well, permittees should verify that the well has been properly developed. Suspended particles and sediment in ground water samples, due to improper well development, interfere with some chemical analyses and can lead to compliance problems and additional financial outlays.

Generally wells are sampled initially after construction, prior to land application activities, to establish a valid background concentration for constituents requiring routine monitoring. Thereafter, monitoring frequency will be determined by the schedule specified in the permit.

7.5.1.4 Reporting Requirements

Ground water monitoring data must be reported in the annual and/or monthly or other frequency reports. Be consistent in reporting well location and identification numbers, and designate each well as upgradient or downgradient in relation to the land application site. Identify wells using the serial numbers designated in the current permit.

7.6 Rapid Infiltration Basins

Rapid infiltration (RI) systems, also known as soil aquifer treatment systems, are highly permeable infiltration basins that are operated using periods of wetting and drying cycles at set frequencies to provide for both anaerobic and aerobic treatment of the recycled water through the vadose zone. The drying cycles are necessary to allow the soil to re-aerate between applications thereby allowing the aerobic microbial population that provides treatment to reestablish. The ratio of wetting/drying in successful RI systems varies based on the soil characteristics and treatment objectives, but it is always less than 1.0.

RI systems accomplish treatment through physical, chemical, and biological interactions in the soil matrix. Vegetation typically has a marginal role in RI systems and is not generally utilized by this treatment method.

RI systems shall be designed to provide even distribution of recycled water, prevent erosion, and ensure proper operation during winter conditions in cold climate areas.

Discharge to an RI system may not exceed the hydraulic, organic, nitrogen, suspended solids, or other limitations specified in the permit. Discharges from an RI system shall be in compliance with the “Ground Water Quality Rule” (IDAPA 58.01.11) and “Water Quality Standards” (IDAPA 58.01.02).

7.7 Summary

In conclusion, the soil-plant system can effectively treat wastewater constituents and prevent them from reaching ground water if the system is properly sited, operated, and maintained. It is important to remember that soils vary tremendously in their treatment capacity. Under some conditions, constituents may take months or years to move from the soil surface to the ground water. Under other conditions, constituents can flow almost directly into the ground water. Once constituents reach the saturated zone, they are available for withdrawal from a drinking water well or discharge to adjacent surface waters, possibly jeopardizing both public health and environmental quality.

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8 Recycled Water Disinfection and Buffer Zones

Need-to-Know Criteria
Buffer zones
Buffer zone reductions through mitigation measures

Two important aspects of any land application site are disinfection, which destroys disease-producing organisms and buffer zones, which minimize public health impacts, nuisance conditions, and aesthetic concerns.

8.1 Disinfection

Disinfection is generally the last form of treatment prior to land application for municipal systems, although there may be a few industrial systems that disinfect. The purpose of disinfection is to destroy disease-producing microorganisms or pathogens. As discussed in section 5.3.1, pathogens can cause many illnesses, such as typhoid fever, amoebic dysentery, and infectious hepatitis.

The disinfection process should be economical, operationally practical, and environmentally acceptable. Three major types of disinfection are used:

- Chlorination
- Ultraviolet radiation
- Ozone

8.1.1 Chlorination

Because of its simple feed and control procedures, its ability to disinfect water with low dosages, and its relatively low cost, chlorination is the most prevalent form of disinfection in the United States today. However, heightened awareness of the safety issues and environmental concerns associated with chlorine use is decreasing its popularity.

Chlorine reacts with many compounds present in recycled water. Nitrogen compounds (including ammonia) react with chlorine to produce chloramines. These chloramines are considered to be relatively effective disinfectants. However, many of the compounds formed when chlorine reacts with non-nitrogen compounds are ineffective as disinfectants.

Chlorine reacts with non-nitrogen compounds before it reacts with nitrogen compounds. Therefore, enough chlorine must be added to react with the non-nitrogen compounds and ensure that enough chlorine is still available for the formation of chloramines. Less chlorine is required to disinfect a higher quality effluent than a poorer quality effluent because there are fewer compounds with which the chlorine may react.

Chlorine dosage is the amount of chlorine that is added to a given volume of water. *Chlorine demand* is the amount of chlorine that is not available as a disinfectant because of reactions with various compounds. *Chlorine residual* is the amount of chlorine that is available for disinfection after a specific contact time. Three terms are usually used in reference to chlorine residual:

- Combined chlorine residual
- Free chlorine residual
- Total chlorine residual

Figure 8-1 is used in the following discussion. When chlorine is added to recycled water, some of the chlorine is used in oxidizing a variety of compounds in the water and does not contribute to chlorine residual (between points A and B). Additional chlorine then reacts with ammonia in the water producing chloramines, contributing to the chlorine residual (between points B and C, and referred to as the combined chlorine residual). As chlorine is added, the pH changes and allows the destruction of the chloramines resulting in the release of nitrogen gas and nitrous oxide to the atmosphere, reducing the combined chlorine residual (between points C and D). At point D, most of the chloramines have been oxidized, which is called break point chlorination. Continued addition of chlorine after the break point, will result in a free chlorine residual increase at the same rate as the applied dosage (Qasim 1999).

Total chlorine residual is the sum of the combined chlorine residual and the free chlorine residual. Therefore, prior to the break point, the total chorine residual is equal to the combined chorine residual (since the free chlorine residual equals zero). After the break point, the total chorine residual is equal to the combined chorine residual, at break point, plus the free chlorine residual.

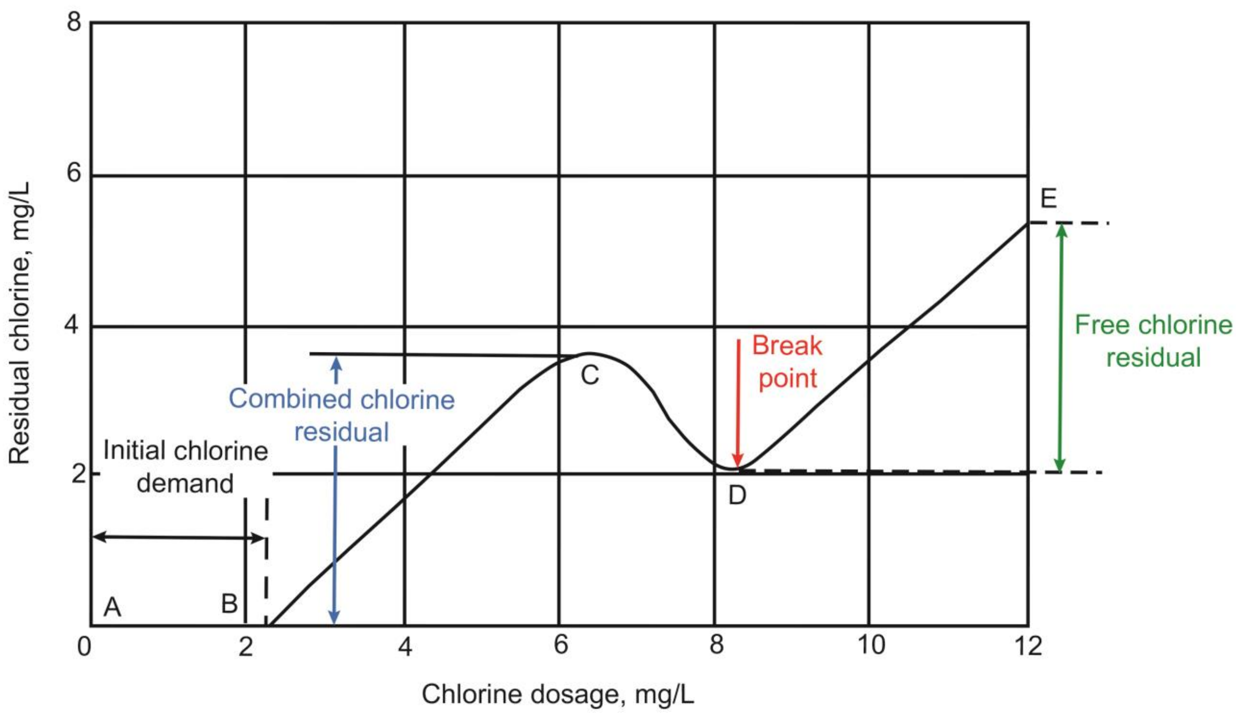

Figure 8-1. Chlorine residuals and the break point chlorination curve (modified from Qasim 1999).

Chlorine contact chambers are generally designed so that the chlorine injection point is below the surface of the water to prevent volatilization. Chambers should also be designed to prevent short-circuiting. Higher chlorine concentrations, longer contact times, and higher temperatures increase the effectiveness of chlorination, while higher pH (above 7.0), total suspended solids, and organic content decrease effectiveness.

Chlorine disinfection is generally accomplished by one of the following methods:

- Gas or liquid chlorine
- Hypochlorite (sodium or calcium hypochlorite)
- Chlorine dioxide

Chlorine is highly toxic and is corrosive in moist atmospheres. Because of the corrosive nature of chlorine, leaks should be repaired as quickly as possible to prevent a minor leak from becoming a major leak.

Note
The safety measures are not mentioned here, and the Occupational Safety and Health Administration (OSHA) should be contacted regarding specific chlorine safety regulations.

8.1.2 Ultraviolet Radiation

UV radiation uses lamps that emit wavelengths of light that are invisible to humans. UV radiation kills bacteria and viruses in water by destroying their cellular genetic material, thereby preventing cell replication. Unlike chlorine, UV radiation leaves no residual in the water and adds nothing except energy that produces some heat. UV light is generally considered as an alternative to chlorine disinfection. A typical ultraviolet disinfection unit is shown in Figure 8-2.

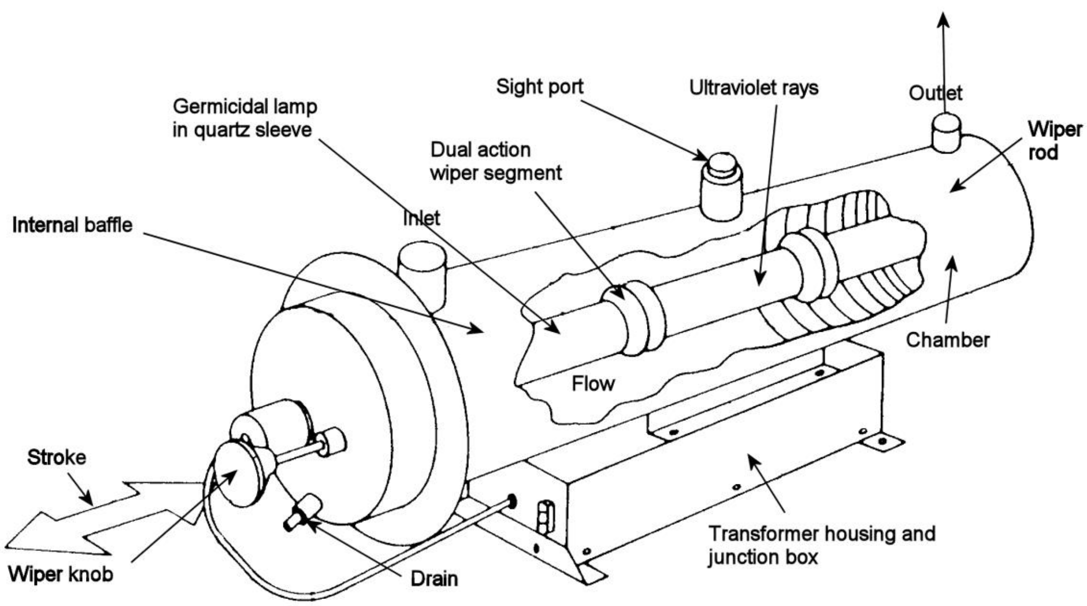

Figure 8-2. Typical ultraviolet disinfection unit (WEF 2004).

The advantages of UV disinfection are that there is no toxic residual, it kills microorganisms including pathogens, and the UV equipment occupies little space. The disadvantages of UV are the lack of a measurable residual (which makes immediate control of the process difficult), the lack of methods for measuring dosage, and the need for a lower suspended solids and color concentration in order for it to be effective. For UV disinfection to be effective, the water must be relatively clean (low turbidity) and clear; UV tubes must be kept submerged and cleaned periodically; and organisms must come into direct contact with the UV light.

8.1.3 Ozone Disinfection

Ozone is not widely used for disinfection. Ozone is an unstable gas that is produced when oxygen molecules are disassociated into atomic oxygen and then collide with another oxygen molecule. Like chlorine, ozone is a strong oxidizing agent and destroys microorganisms by attacking the cell walls. It is faster acting and more effective than chlorine in destroying viruses and bacteria.

Because it is chemically unstable and decomposes to oxygen very rapidly, ozone must be produced continuously and must be used as it is produced. Ozone is bubbled through the recycled water in a closed contact chamber with fine bubble diffusers covering the bottom of the chamber. After contact time, ozone is then collected off the top of the contact chamber and destroyed.

Ozone is extremely irritating and can be toxic. To be effective, ozone disinfection requires high transfer efficiency, good mixing, adequate contact time, and minimal short-circuiting in the contactor.

The advantages of using ozone as a disinfectant include the lack of a toxic residual, an increase in effluent dissolved oxygen levels, almost instantaneous disinfection action, and ozone’s relative insensitivity to pH. Disadvantages include higher capital and operational costs and a lack of reliable automatic control systems.

8.2 Buffer Zones

A buffer zone is the area beyond the perimeter of a land application field, which provides the minimum separation needed to reduce the potential for impacts to public health and the environment as well as minimizing nuisance conditions and aesthetic concerns. Three parts factor into a site’s buffer zone requirements: (1) buffer zone distances to land uses of concern, (2) posting requirements, and (3) fencing requirements. These methods limit public access and contact with recycled water.

Land uses of concern for which DEQ has established guideline buffer zone distances are areas of public access, surface waters, public or private drinking water supplies, and occupied dwellings. The guideline buffer zone distances are a function of the following:

- The characteristics of the land-applied water (industrial or municipal)
- Level of treatment and disinfection designed for the land application site (Class A, B, C, or D municipal effluent, industrial)
- Location of the land application field (suburban/residential or rural/industrial or residential)
- Mode of irrigation (sprinkler or furrow)

For example, allowing spray mist from a land application sprinkler irrigation system to drift onto adjoining properties has the potential to create aesthetic, nuisance, and public health impacts. General buffer zone distance recommendations for various land uses of concern are as follows:

- Inhabited dwelling: 300 feet
- Private water supply well: 500 feet
- Public water supply well: 1,000 feet
- Public access areas: 50 feet
- Permanent or intermittent surface water: 100 feet
- Temporary surface water and irrigation ditches and canals: 50 feet
- In general, DEQ’s guideline buffer zone distances decrease with greater disinfection (lower total coliform counts). In addition, all buffer zone distances must comply with and not supersede local zoning ordinances. Refer to the DEQ guidance for a detailed discussion of buffer zones.
- In section 2, the disinfection levels of the various classes of municipal recycled water are presented in Table 2-1, Table 2-2, and Table 2-3.

The buffer zone distances specified in a reuse permit may vary from DEQ’s guidance distances due to site-specific characteristics. For example, buffer zone distances may be reduced through the following mitigation measures:

- Establish an effective physical or vegetative barrier to reduce drift or aerosol dispersion
- Use *nonspray* irrigation (drag tubes or equivalent apparatus)
- Manage irrigation systems in a manner that prevents any spray drift towards the land use of concern
- Use runoff and/or overspray controls

Combining best management practices (BMPs) with standard buffer zone distances to help protect drinking water supplies. Monitoring well buffer zone distances are typically less than drinking water well buffer zones and also depend on the types of BMPs used. Monitoring well buffer zone distances may vary from site to site and are specified in the site permit. Also note that reuse facilities with existing or planned cross-connections or interconnections between the recycled water system and any water supply (potable or nonpotable), or surface water, shall have backflow prevention assemblies, devices, or methods as required by the applicable rule or as specified in permits and approved by DEQ. Example BMPs for drinking water wellhead protection include installing a backflow assembly and grading the ground to direct any waters away from a wellhead.

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9 Lagoons

Need-to-Know Criteria
Lagoon design and configuration: slope, freeboard, liners, liner integrity, and short-circuiting
Lagoon operation and maintenance: vegetation, erosion, excessive algae, odor prevention, insufficient freeboard, short-circuiting, and fencing and posting

A lagoon (or pond) can provide treatment or storage (e.g., during winter months or during maintenance). Although a limited amount of treatment may occur in storage lagoons, they are designed primarily for storage. This section addresses the role of storage lagoons at land application sites. Treatment lagoons are covered as part of wastewater treatment operator certification obtained previously.

9.1 Lagoon Design and Configuration

Lagoons are generally designed and constructed with earthen dams or dikes. The inner dikes of new lagoons are typically lined with a synthetic material to prevent leakage. Figure 9-1 shows a typical lagoon design. Generally, inner and outer dike slopes shall not be steeper than 3 units horizontal to 1 unit vertical for slope stability and maintenance (i.e., mowing, erosion control, slope stability, and weeding). Lagoons must be designed for a minimum freeboard (the distance between the top of the dike at its lowest point and the highest allowed wastewater level within the lagoon). This design provides a safety factor so that the lagoon does not overtop its banks from wave action, higher than planned water entering the lagoon, or heavy precipitation events. For existing lagoons using clay or earthen liners or lagoons that have a buried synthetic liner, the inside slopes may be protected by riprap from 1 foot below the minimum water surface to the top of the freeboard to protect against wave erosion.

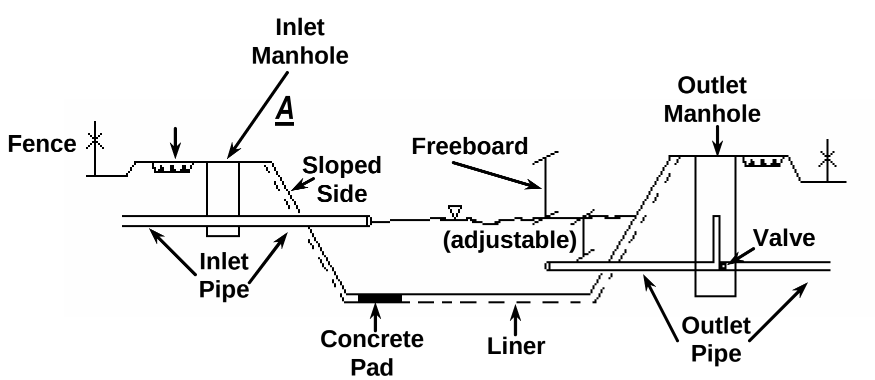

Figure 9-1. Typical lagoon design (Water Pollution Control Federation and Environment Canada 1981).

Liners are used to minimize the loss of wastewater to the subsurface or ground water by reducing the permeability of the bottom and sidewalls of the lagoons. Lagoons need a minimum separation of 2 feet between the bottom of the pond and the maximum ground water elevation.

The typical materials used for liners are synthetic membranes, compacted clay, and bentonite. New installations typically use high density polyethylene (HDPE) or buried PVC liners. Clay and bentonite liners require submergence in water to retain their sealing characteristics. If exposed and dried, clay and bentonite liners may develop cracks and lose their ability to provide a good seal.

Design and operating standards allow seepage rates from lagoons. As such, lagoons are required to be periodically seepage rate tested to evaluate liner integrity. Lagoon seepage above DEQ performance criteria generally requires repair, replacement, or abandonment of the lagoon.

Municipal wastewater lagoons must meet facility-specific seepage rates corresponding to the date of construction (or major modification) every 10 years after initial testing. Industrial facility seepage testing is required by permit and its frequency of testing is based on the permit. Lagoons must be seepage tested if a change in liner condition occurs that affects its permeability, including but not limited to, liner repair below the high water line, liner replacement, lagoon dewatering of soil-lined lagoons, which results in desiccation of the soil liner, seal installation, or earthwork affecting liner integrity. Recycled water enters and leaves a lagoon through inlet and outlet pipes. Inlet structures should be located so that water is distributed evenly in the lagoon. If water is gravity fed to the lagoon, a concrete pad or riprap is often placed at the end of the inlet pipe to protect the lagoon liner. If the lagoon is used for chlorine treatment, the outlet pipe is located as far as possible from the inlet pipe to increase chlorine detention time and to prevent *short-circuiting* (a condition where some of the water in a lagoon travels faster than the rest of the water, between the inlet and outlet pipes). Short-circuiting is especially a problem in lagoons that are designed to allow for a specific *chlorine contact time* (the amount of time chlorine must be allowed to react with the water prior to discharge and reuse).

The following factors are used to determine the volume of lagoon storage capacity that is required:

1. If the land application system is designed for growing season only application, the lagoon is designed for storage of effluent throughout the nongrowing season.
2. If the land application system is designed with a nongrowing season application allowance, storage may be necessary for periods of extreme cold temperatures, which can prevent application due to freezing problems in the irrigation system, frozen soils, or ice buildup on the application site.
3. If land application is not possible due to harvesting or heavy precipitation events.
4. If an alternative discharge point such as a National Pollutant Discharge Elimination System (NPDES) permit or rapid infiltration basin is available.

Other design considerations for lagoons include the following:

- Multiple cells to provide access during maintenance
- Proximity to surface waters and drinking water wells
- Potential for odor generation, aeration for odor reduction, and siting
- Permanent stilling wells for seepage testing

9.2 Lagoon Operation and Maintenance

Regardless of how well-designed, lagoons will not perform to their optimum potential unless properly operated and maintained. Inspections and sampling should be conducted on a routine basis to determine if any problems are apparent. Routine operation and maintenance practices should address and control the following conditions and situations:

- Emergent (rooted) plants
- Suspended vegetation
- Erosion
- Excessive algae
- Odor production
- Insufficient freeboard
- Short-circuiting, if chlorine treatment is a component of the storage lagoon
- Sludge depth and removal
- Not running aerators as designed and/or required

In addition, other basic management steps are both recommended and required. These steps include posting and maintaining warning signs and fencing to discourage unauthorized access (from people and livestock) and protect public health and safety.

9.2.1 Vegetation

Controlling vegetation around lagoons is important. Weeds and grasses on dams and dikes provide sheltered areas for insects and burrowing animals, interfere with the establishment and maintenance of a desirable vegetative cover, and hinder visual inspection of dikes. Trees and other deep-rooting vegetation can impair the structural integrity of lagoon dikes. Regular mowing and weeding are required to avoid these problems.

Rooted plants growing on the bottom of the lagoon (emergent growth) and suspended vegetation in lagoons takes up valuable space, provides a breeding ground for potential vectors, such as mosquitoes, and hinders pond circulation. In addition, dead vegetation can contribute to BOD levels, reduce dissolved oxygen, and cause odors.

Emergent growth will occur when sunlight is able to reach the lagoon bottom in older lagoons with earthen bottoms or lagoons with a buried synthetic liner. Emergent growth can be controlled by the following:

- Immediate removal of young plants (including roots)
- Drowning weeds by raising the water level and preventing sunlight from reaching the plants
- By installing pond liners
- As a last resort, using herbicides (which should only be used with the approval of the DEQ and taking into consideration impacts to the land application fields)

Vegetation, such as duckweed and algae can occur in any lagoon, regardless of depth. Often mistaken for algae, duckweed floats on a lagoon surface and has long hair-like roots that hang down into the water. It grows rapidly and can cover the entire surface of a lagoon if not controlled. If suspended vegetation is a problem, it should be skimmed off with rakes or other tools or mechanically harvested. As a last resort, a herbicide can be used by adhering to the precautions outlined above. If not removed, vegetation may plug the irrigation system.

Ducks eat duckweed (hence, the name) and may control a light growth of suspended vegetation. Fecal waste from ducks and other waterfowl, however, can contribute BOD to the lagoon and increase coliform levels. Depending on the required disinfection level, the attraction of waterfowl to a lagoon may seriously impact the water quality. Disinfection downstream of the lagoon may be necessary in some cases to achieve the required water quality levels.

9.2.2 Erosion

Erosion can wash away clay liner material on inside banks or create cracks and crevices in outer banks. Both situations reduce the structural integrity of lagoon dikes and can result in leaks and dike failure. Erosion can be caused by wave action, surface runoff from precipitation, holes dug by burrowing animals, access by wildlife, lack of proper vegetation on outside slopes (lagoon dikes), steep slopes, or poor maintenance.

Slope stabilization through the installation of riprap or broken concrete along banks and dikes can minimize erosion and limit weed growth. However, this practice cannot be used for exposed synthetic liners.

Diversion ditches and proper grading around the lagoon may be used to divert surface water away from the lagoon. Burrowing animals, such as gophers, moles, ground squirrels, and groundhogs, should be trapped and removed. Burrowed holes should be repaired immediately to prevent erosion.

9.2.3 Excessive Algae

Excessive algae growth can create serious problems. Algae blooms die off as suddenly as they appear, blocking sunlight, and the dead vegetation can cause foul odors. The die-off of algae blooms also causes a very high BOD loading, which reduces dissolved oxygen levels, and the lagoon may become anaerobic or septic and cause odor problems.

A specific type of algae that can be problematic is blue-green algae (cyanobacteria). A bloom (rapid growth) of blue-green algae can be caused by organic overloading, nutrient overloading, high water temperatures, or stagnant conditions and foul odors.

Blue-green algae are photosynthetic bacteria that grow in fresh water lakes, ponds, and wetlands, as well as wastewater lagoons. They usually occur only in small numbers and are so small they are invisible to the casual observer.

When a bloom occurs, huge numbers of algae grow and accumulate on the surface of the lagoon, to the point where the surface of the water resembles thick pea soup, often blue-green in color. Although these blooms occur naturally, water bodies that have been enriched with plant nutrients from municipal, industrial, or agricultural sources are particularly susceptible to these growths.

Blue-green algal blooms are unsightly, but more important, blue-green algal blooms can be toxic if ingested by wildlife, livestock, or people. Blue-green algae produce neurotoxins that affect the nervous and respiratory systems and hepatotoxins that affect the liver function.

If blue-green algal blooms are suspected, they should be treated with caution. One of the first signs of toxin contamination in a water body is the presence of stressed, sick, or dead wildlife or waterfowl. Contact DEQ or the local health district if you suspect a problem. Water suspected of being contaminated with toxic strains of blue-green algae can be sampled and tested for toxicity.

Algae mats should be broken up and dispersed or physically removed like duckweed. Algae can also be controlled by physical, chemical, and biological means, such as the following:

- Lagoon covers (artificial or natural) eliminate sunlight, photosynthesis, and vegetative growth.
- Aeration or mixing removes carbon dioxide from the water and reduces plant growth.
- Shock chlorination at high doses for short duration and at a lower chlorine dose for longer duration have both been used successfully in controlling algae.
- Copper sulfate is the most common chemical used to control algae.
- Nontoxic dyes to reduce sunlight penetration in the water.

Note
When considering any chemical or biological means of algae control, the WWLA operator must ensure that the action is approved by the DEQ and is not a violation of permit conditions.

9.2.4 Odor Prevention

Some lagoons can produce odors from time to time, depending on the water quality of the stored water and how the ponds are maintained and operated. If odors are a problem or anticipated to be a problem, an odor management plan must be submitted to and approved by DEQ.

The odor management plan should cover water treatment systems, land application facilities, lagoons, and other operations associated with the facility. The plan should include specific design considerations, operation and maintenance procedures, and management practices to be employed to minimize the potential for or limit odors. The plan should also include procedures to respond to an odor incident if one occurs.

Odors related to lagoons may be caused by the following:

- Storage of recycled water with a high organic content
- Stagnant conditions or long detention times of water in storage
- Lagoon turnover due to seasonal temperature changes. This causes a vertical movement of the lagoon contents causing the lower anaerobic zone to move towards the surface
- Organic overloading (may be caused by the accumulation of dead vegetation or algae) of the lagoon

Most odors in the lagoon water column are caused due to anaerobic conditions, which generate odorous gases such as hydrogen sulfide and mercapans.

9.2.5 Insufficient Freeboard

A properly designed lagoon system will provide adequate freeboard or safety volume to prevent an overflow from the lagoon. Overflow from lagoons, for any reason, is a violation of state rules and is subject to enforcement action. Allowing a lagoon to reach its maximum storage capacity before the start of the nongrowing season does not leave room for storing excess precipitation during extended wet periods. In the late summer and early fall, lagoons are typically pumped down as far as possible.

In Idaho, lagoons are designed to have a minimum of 3 feet of permanent freeboard unless they are under 50,000 gallons/day for which 2 feet may be acceptable. Under normal operations, the freeboard space will not be used for water storage. However, under some conditions, the freeboard space may be encroached upon:

- Extremely high precipitation event.
- High flow into the lagoon from situations such as rapid population growth, inflow and infiltration problems, or in industrial systems, plant upsets or unusual operations resulting in greater generation of recycled water.
- Inability to lower lagoon volume to minimum levels prior to the winter storage season.
- If a situation arises that could result in approaching a lagoon overflow, or as the minimum freeboard level is encroached upon, contact the DEQ regional office to evaluate the situation and to determine what actions and approvals may be needed.

9.2.6 Short-Circuiting

Short-circuiting is a condition that occurs when some of the water in a lagoon or basin travels faster than the rest of the flowing water, typically between the inlet and outlet pipes. This problem can be caused by poor design, sludge accumulation in the lagoon bottom, vegetation that hinders lagoon circulation, and temperature gradients in the water column (lagoon turnover).

Short-circuiting is a bigger concern for lagoons that perform treatment or are used for chlorine disinfection. It is of less of a concern for lagoons used solely for storage. However, if the short-circuiting causes stagnant conditions in a portion of the lagoon, it can cause odor problems depending on the water quality. Short-circuiting can be verified by the use of dye tests and may be corrected or prevented by using curtains or baffles to redirect flow, relocating inlet and outlet pipes, controlling vegetation, and removing excessive sludge deposits from the lagoon.

9.2.7 Sludge Accumulation and Removal

Sludge is the semisolid or solid material in sewage that separates out during treatment. Sludge levels should always be evaluated as too much sludge can displace water volume and create channeling or short-circuiting of the wastewater and create problems that cause inadequate wastewater treatment. It is not expected that storage lagoons will accumulate a significant amount of sludge since the storage lagoon generally follows after treatment. The sludge accumulation rate is important for planning and determining the need for sludge removal. Sludge accumulation is affected by many variables, including hydraulic and organic loading pretreatment, temperature, and lagoon design.

A sludge inventory assesses the amount and locations of solids in the lagoon. Many options are available for sludge removal, and a state-approved sludge removal plan is often requried prior to sludge removal. The removed sludge is subject to state and federal rules, and the lagoon owner is generally considered the responsible party legally as the generator of the sludge. Municipal and industrial sludge may have different state and federal rule requirements. Sludge may contain pathogens, nutrients, and heavy metals. Sludge may be disposed of or beneficially used for soil augmentation. Treated sludge is called biosolids. Biosolids when treated are safe for beneficial use for soil augmentation, which include use for crop nutrients. Sludge may also be disposed of at land fills if the land fill will accept it. Requirements for land fill disposal include dewatering and testing for heavy metals.

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10 Distribution Network and Devices

Need-to-Know Criteria
Pump discharge: flowmeters and counters
Distribution network and devices: fittings, sprinklers, solid set irrigation equipment, and center pivots
Operational issues: as-built plans, backflow devices, system pressure, and system discharge flows

The WWLA operator needs a basic understanding of pumps and their controls as well as an understanding of distribution networks and their devices. In most cases, WWLA operators will be operating and maintaining equipment and systems that were designed and installed by someone else. WWLA operators will have greater success in operating and maintaining a distribution system that was properly designed and installed, but even a good design does not guarantee that recycled water will be properly applied. Poor operation can adversely affect the performance of a well-designed system. Conversely, careful operation of a poorly designed system can sometimes provide a good performing land application system.

10.1 Pumps and Controls

10.1.1 Pumps

A pump is a mechanical device that imparts energy to liquids to move the liquids from one location to another. Generally irrigation pumps operate on the following principals:

- Air is exhausted from the working chamber.
- Atmospheric pressure forces water (or another liquid) into the chamber.
- The pump mechanism forces the water out of the chamber, creating a partial vacuum.
- Additional water fills the chamber to repeat this cycle.

The general concepts associated with pumps and controls are found in Appendix D.

10.1.2 Backflow Prevention Assemblies and Devices

Reuse facilities with existing or planned cross-connections or interconnections between the recycled water system and any water supply (potable or nonpotable), shall have approved backflow prevention assemblies or devices as required by the applicable rule or regulation and approved by DEQ.

- Approved backflow prevention assemblies are a category of backflow preventers that have been evaluated and certified to meet certain standards. Third party approval organizations certify assemblies to meet certain material, design, and performance standards. They must meet performance standards that include pressure loss, head loss, and flow requirements. Assemblies are mechanical backflow preventers designed to be tested and repaired in-line (AWWA 2012).
- Devices are mechanical backflow preventers that do not meet the specific approval requirements of an assembly. Devices are generally nontestable and not repairable in-line (AWWA 2012).

There shall be no connection between drinking water distribution systems or ground water wells and any pipes, pumps, hydrants, water-loading stations, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into a public water system or ground water well. The WWLA operator is responsible through backflow prevention assemblies and devices to take reasonable and prudent measures to protect the water system against contamination and pollution from cross connections. An approved backflow assembly is strongly recommended to be installed on the discharge from an irrigation well to prevent ground water contamination.

The assemblies shall be adequately maintained, shall be tested annually by a certified backflow assembly tester, and repaired or replaced as necessary to maintain operational status. Records of backflow assembly test results, repairs, and replacements shall be kept at the reuse facility along with other operational records and shall be discussed in the annual report and made available for inspection by DEQ. Other approved means of backflow prevention, such as siphons and air-gap structures that cannot be tested, shall be maintained in operable order.

Backflow prevention may be required on a case-by-case basis, as determined by DEQ, to isolate different classes of recycled water.

10.1.3 Alarms and Timers

Alarms are controls with visual and/or audible signals that indicate that a condition exists in the system requiring the WWLA operator's attention. The alarms vary from a simple high water level alarm to a multiple alarm system. The most common and necessary is the high water alarm. High water alarms can be activated using the same ON/OFF controls used to sense water-level changes. Alarms may be needed for other parameters such as temperatures, pump, power, and seal failures.

Timers are devices that allow the WWLA operator to control pumps or controls in specified ways at predetermined times. *Run cycle timers* repeatedly open and close contacts according to preset time cycles while pump run timers are helpful in calculating the volume of discharged water.

10.1.4 Counters

Counters measure pump activity related to flow. Counters provide flow indication for timer panels. A counter can be used to add up the number of times the pump has been activated, or for run counters, used to calculate the volume of discharged water.

10.1.5 Flowmeters

Flowmeters are instruments for measuring the amount (flow volume) or rate (velocity) of water flow. It is necessary to know the flow rate in a treatment system so that adjustments can be made to pumping rates, chlorination rates, and other processes in the system. Water flow rates must also be known for calculating hydraulic and constituent loadings at a land application site.

Elapsed time meters are used to record the amount of time each pump runs. This is a good way to monitor the hours per day that a pump runs. One elapsed time meter is used per pump. If a flowmeter is not installed or operational on the discharge line, WWLA operators might be able to use, under certain conditions a combination of pump run timers, knowledge of the operating characteristics of the pump, and the manufacturer's pump performance curve to estimate the flow (or volume) of applied water.

Flow-measuring devices must be periodically calibrated to ensure a known pump discharge rate and ensure their continued precision and accuracy. Most manufacturers and dealer representatives will offer a service and maintenance agreement with a flowmeter for its periodic calibration. Calibration is recommended per manufacturer specified frequencies, and when conditions or damage (e.g., lightning) has occurred that could affect the accuracy of the meter.

Comparing flow measurement against other methods of flow estimation can also help to calibrate pump discharge rates. For example, total flow in a pump cycle may be estimated by knowing the discharge rate from a sprinkler based on nozzle size and pressure (which gives gallons per minute) and multiplying this value by the total pump run time.

Another standard to check against is pump *drawdown* in a tank or wet well, or lagoon level drawdown. To estimate flow rate by the pump drawdown method, other inflows and outflows to the tank or lagoon must be shutoff or precisely measured.

The WWLA operator should use all appropriate techniques to help with flow management and calibration for a land application system.

10.2 Distribution Network and Devices

To ensure the appropriate amount of water is uniformly applied at a land application site, WWLA operators must be familiar with common types of irrigation application devices (sprinklers), irrigation system design, correct pressure settings, and other distribution system operating issues.

10.2.1 Pipes and Fittings

10.2.1.1 Pipes

A piping system consists of the pipes, fittings, and appurtenances within which a fluid flows. WWLA operators should be familiar with pipes, connections, and valves. General information is found in Appendix E.

10.2.1.2 Fittings

Pipe fittings are joints or connectors between pieces of pipe. Examples are *elbows* that alter the direction of a pipe; *tees* and *crosses* connect a branch with a main; *plugs* and *caps* close an end; and *bushings*, diminishers, or reducing sockets couple two pipes of different dimensions.

Pipe *cleanouts* should be used whenever recycled water has a solids content that causes the potential for solids buildup and clogging in piping. Cleanouts are also advised at sharp turns in piping, such as elbows, where water tends to slow down. A pipe cleanout is typically a *wye* fitting (a pipe fitting with three branches positioned in one plane in a pattern of the letter Y) that is installed several feet up-flow from the appropriate area to be cleaned, typically at elbows or sharp turns. The *dead end* of the wye is at the ground surface or above for easy access and is capped off with a threaded plug. This access must be protected from equipment and traffic. The cleanout allows the WWLA operator to clean the piping with plumbing snakes, augers, or water pressure cleaners.

Thrust blocking is used in irrigation systems, using moderate-to-high water pressures to protect the distribution system from damage that could be caused by water pressure. Thrust blocking is used at all points at which water flow either changes direction (such as tees and elbows) or comes to a dead end (ends of laterals or field valves). The thrust block, which is typically a mass of concrete, must lie against natural ground to offer the most protection. Pipe excavation for repair at any of these points is likely to encounter concrete thrust blocks, which must be replaced when replacing pipe or fittings where water changes direction.

10.2.2 Irrigation Application Devices (Sprinklers)

Sprinklers, drip emitters, and other devices are used to distribute water to the land application fields. Many people consider the application devices (sprinklers) to be the heart of the irrigation system, but a well designed and properly functioning pumping system is critical to the operation of the sprinklers. However, most WWLA operators will spend much of their time dealing with sprinkler management, maintenance, and repair. Sprinkler maintenance and operation is a key component of successfully managing a land application system.

Many types of irrigation application devices are available. Most are not designed for recycled water containing solids, but some have been adapted for this use. Many irrigation devices function well where recycled water is very dilute and has few solids or chemicals. It is beyond the scope of this manual to discuss all types of equipment available. The WWLA operator should be familiar with the basic terms describing irrigation equipment and the factors that affect the operation of that equipment. When purchasing irrigation equipment, always notify the dealer that the equipment will be used in a recycled water setting.

Some common types of irrigation application devices (sprinklers) are described below:

- Nozzle—The part of the sprinkler where the water discharge occurs. Important factors are nozzle type (plastic, brass, taper bore, or ring) and nozzle size at the opening (in inches).
- Full circle sprinkler—A sprinkler that turns 360 degrees and wets a total circle. These sprinklers are used in the interior and exterior positions of land application fields.
- Partial circle or partial turn sprinkler—A special sprinkler that allows the WWLA operator to direct discharge to a select portion of the field. Devices such as clips or threaded stops cause the sprinkler to rotate part circle (less than 360 degrees). These sprinklers are often used to prevent irrigation into buffers, roadways, ditches, or problem areas in the field. Note that using partial turn sprinklers, without changing other parameters, such as nozzle size or pressure, results in an increased water application rate. For example, a half turn sprinkler with the same settings as a full turn sprinkler will apply two times as much water per hour to the area it irrigates. Partial turn sprinklers must be operated very carefully to avoid ponding and runoff.
- Gun—Usually refers to a large sprinkler with nozzle opening exceeding one-half inch. A gun is usually mounted onto a permanent riser of 2-inch pipe size or larger, a traveling gun cart, or the distal end of a center pivot system.

- Rotary head sprinkler—A sprinkler whose head rotates around the base due to a swinging, spring-loaded impact arm. The water pressure throws the arm to the side; it returns due to the spring, and intercepts the water stream, causing the sprinkler to rotate several degrees. These sprinklers are much more moderately priced than guns.
- Microspray heads—Devices that distribute water in a variety of patterns other than the rotary impact sprinkler head described above. Water is deflected via vanes, grooves, wobbling weights, and other devices that allow for water distribution. Usually, these are used with lower pressures (5 to 30 pounds per square inch [psi]), and often are used to reduce wind drift. The length of water throw is limited, thus requiring close spacing.
- Drip emitters—Installed in flexible (PVC, polyethylene) tubing (hoses). Drip emitters allow water that is under pressure inside the tubing to be emitted at low pressures. Usually, this type of piping is installed at the ground surface or slightly under the ground surface to provide water uptake by plant roots. The drip emitter consists of a labyrinth inside the hose that allows for pressure drop as the water is emitted and are used to prevent wind drift. The orifice size is about one-sixteenth to one-eighth of an inch and distributes less than 1 gallon per minute.

10.2.2.1 Solid Set Irrigation Equipment

Solid set or stationary systems for land application are usually permanent installations (lateral lines are PVC pipes permanently installed belowground). One of the main advantages of stationary sprinkler systems is that these systems are well suited to irregularly shaped fields. Thus, it is difficult to give a standard layout, but there are some common features between systems.

Sprinkler spacing is based on nozzle flow rate and the desired application rate. To provide proper overlap, sprinkler spacings are normally 50% to 65% of the sprinkler wetted diameter, or in the range of 80 x 80 feet. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. A typical layout for a permanent irrigation system is shown in Figure 10-1.

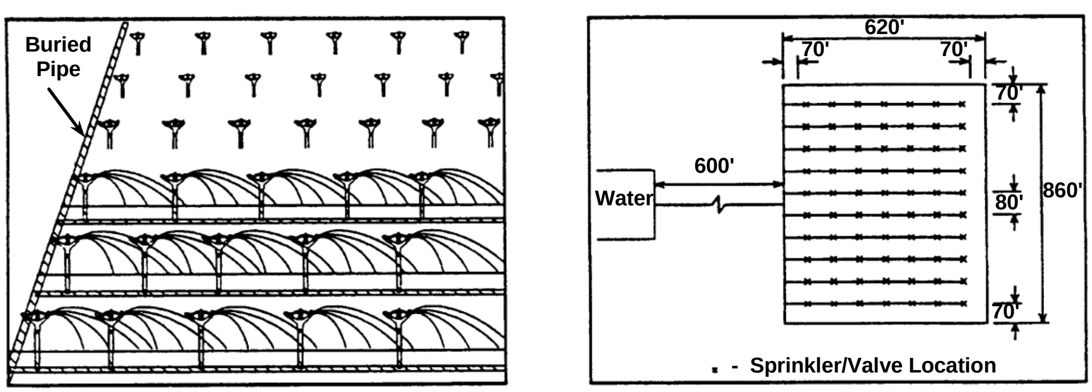

Figure 10-1. Schematic layout of a typical solid set irrigation system.

The minimum recommended nozzle size for recycled water is one-quarter inch. Typical operating pressure at the sprinkler is 25 to 60 psi. Sprinklers can operate full or partial circle. The system should be zoned (any sprinklers operated at one time constitutes one zone) so that all sprinklers are operating on about the same amount of rotation to achieve uniform application. Gun sprinklers typically have higher application rates; therefore, adjacent guns should not be operated at the same time (referred to as *head to head*). Most permanent systems use PVC plastic irrigation pipe for mains, submains, and laterals and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed (Figure 10-2). In grazing conditions, all risers must be protected (stabilized) if left in the field with animals.

The advantages of fixed irrigation equipment include the following:

- Flexible irrigation rates
- Suitability for irregularly shaped fields
- Suitability for tree crops

Disadvantages of fixed irrigation equipment include the following:

- High capital costs
- Limited use for row crops

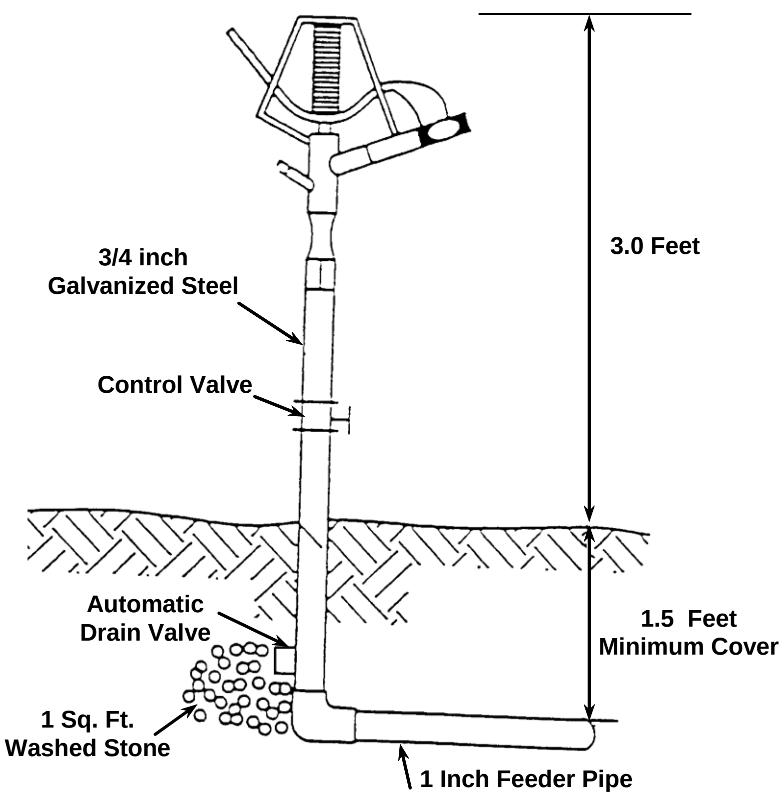

Figure 10-2. Typical spray head for a fixed system.

10.2.2.2 Mobile Irrigation Equipment

Mobile or *traveling* sprinkler systems are either cable-tow, hose-drag travelers, center pivot, or linear-move systems.

10.2.2.2.1 Travelers

The cable-tow traveler consists of a single-gun sprinkler mounted on a trailer with water being supplied through a flexible, synthetic fabric, rubber or PVC-coated hose. A steel cable is used to guide the gun cart.

The hose-drag traveler consists of a hose drum, a medium-density polyethylene hose, and a gun-type sprinkler. The hose drum is mounted on a multiwheel trailer or wagon. The gun sprinkler is mounted on a wheel- or sled-type cart referred to as the *gun cart*. Normally, only one gun is mounted on the gun cart. The hose supplies wastewater to the gun sprinkler and also pulls the gun cart toward the drum (Figure 10-3). A tractor is typically required to move the cart from one location to another because they are typically too heavy for all terrain or passenger vehicles.

Figure 10-3. Hard hose traveler showing reel and gun cart.

The distance between adjacent pulls is referred to as the *lane spacing*. To provide proper overlap, the lane spacing is normally 70% to 80% of the gun wetted diameter. Operating pressures range from 80 to 150 psi. Like stationary sprinklers, traveling guns can operate full or partial circle. A typical layout for a hard-hose traveler irrigation system is shown in Figure 10-4.

The hose drum is rotated by a water turbine, water piston, water bellows, or by an internal combustion engine. Regardless of the drive mechanism, the system should be equipped with speed compensation so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. If the solids content of the wastewater exceeds 1%, an engine drive should be used.

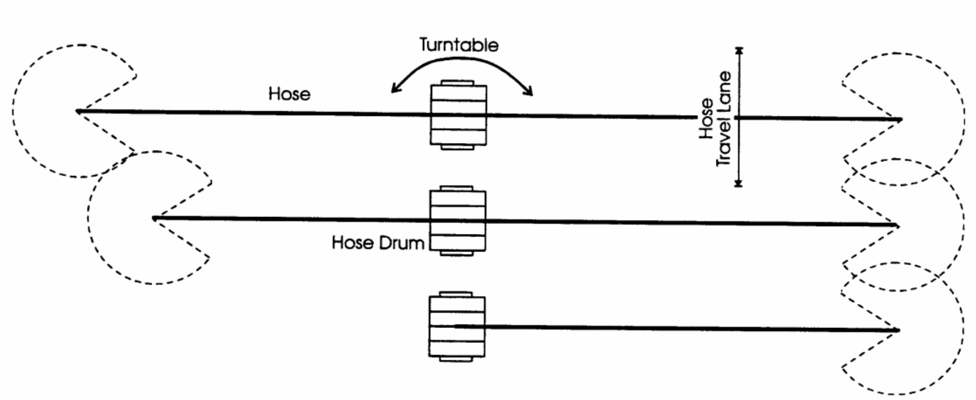

Figure 10-4. Schematic layout of a hose-drag traveler. Travel lanes are 100 to 300 feet apart, depending on sprinkler capacity and diameter coverage.

Nozzle sizes on gun-type travelers range from 0.5 to 2.0 inches in diameter. Three types of nozzles are *taper bore*, *ring*, or *taper ring*. The ring nozzle provides better breakup of the water stream, resulting in smaller droplets with less impact energy (less soil compaction) and providing better application uniformity throughout the wetted radius. But, for the same operating pressure and flow rate, the taper bore nozzle throws water about 5% further than the ring nozzle (i.e., the wetted diameter of a taper bore nozzle is 5% wider than the wetted diameter of a ring nozzle) resulting in a 10% larger wetted area.

A gun sprinkler with a taper bore nozzle is normally sold with only one size of nozzle, whereas a ring nozzle is often provided with a set of rings ranging in size from 0.5 to 2.0 inches in diameter. This allows the WWLA operator flexibility to adjust flow rate and diameter of throw without sacrificing application uniformity.

Furthermore, on water drive systems, the speed compensation mechanism is affected by flow rate. A minimum threshold flow is required for proper operation of the speed compensation mechanism. If the flow drops below the threshold, the travel speed becomes disproportionately slower, resulting in excessive application although a smaller nozzle is being used. System operators should be knowledgeable of the relationships between nozzle size, flow rate, wetted diameter, and travel speed before interchanging different nozzle sizes.

Advantages of traveling irrigation systems include the following:

- Potential lower capital costs
- Adjustable speed with no interruption of irrigation

Disadvantages of traveling irrigation systems include the following:

- High application rates on large units (0.3 to 1.0 inch per hour)
- Potential runoff and ponding from traveler lanes
- High operating costs (energy)
- Requires two people to operate
- Limited use on forested sites (can result in debarking unless diffusers are used)

10.2.2.2.2 Center Pivots and Linear Move Systems

The use of center-pivot systems for irrigation is increasing. The systems are available in size from single tower machines that cover around 10 acres to multitower machines that can cover several hundred acres. Center pivots use either rotary sprinklers, small guns, drag tubes, or spray nozzles. Operating pressures range from 25 to 60 psi. Drop-type spray nozzles offer the advantage of applying water close to the ground at low pressure, which results in less drift due to wind.

A center pivot device applies water along an elevated distribution pipe that is anchored at one end. Water is supplied at the anchored end and distributed from sprinkler heads mounted to the distribution pipe. The unit is driven by electrical motors mounted at the wheels along the distribution pipe. When properly designed and operated, the application rate of each sprinkler head increases with its distance from the fixed center, so water is uniformly applied as the pivot moves in a circular motion (Figure 10-5 and Figure 10-6). Center pivots typically are used with a programmable control panel that allows the operator to reduce the hydraulic-loading rate over problem areas in a field, such as rock outcroppings, by speeding up the travel time of the center pivot.

Figure 10-5. Center pivot system.

Need-to–Know Criteria
Linear-move systems are similar to center pivot systems, except that neither end of the distribution pipe is anchored, and travel is in a straight line. Water is supplied through a feeder hose to one end of the distribution pipe. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 psi. Low pressure systems reduce drift at the expense of higher application rates and greater potential for runoff.

Figure 10-6. Center pivot control panel.

Advantages of center pivot and linear move systems include the following:

- Excellent irrigation control (programmable)
- Wide range in application rates (0.1 to 1.0 inch per hour)
- Low operating costs (energy, people)

Disadvantages of center pivot and linear move systems include the following:

- High capital costs
- Center pivots fixed to one side (towable pivots available)
- Wheel tracks are potential source of runoff and ponding

10.3 Operational Issues

By understanding the components of the irrigation system, their layout and installation, and by using monitoring devices, the WWLA operator can effectively operate the irrigation system. Troubleshooting problems early can also prevent significant and expensive equipment malfunctions and possible negative impacts to the environment.

The WWLA operator should be familiar with all components that make up a land application facility, including the irrigation system. This is most easily done by maintaining a set of approved *as-built* plans for the facility because design plans do not always reflect what was actually installed during construction.

The as-built plans should provide sufficient detail, so that the WWLA operator can determine the location, size, and type of all pipes, valves, and fittings. This is especially important for buried irrigation mainlines and laterals. This will allow the WWLA operator to perform quick service and repair and keep spare parts on hand. If as-built plans are not on site, a set may be obtained from the design engineer for the facility.

If both recycled water and supplemental irrigation water are applied to the land application fields, determine if the supplemental irrigation water supply is directly connected to the recycled water distribution system. If so, a DEQ-approved backflow prevention device must be installed to protect the quality of the fresh irrigation water supply. If the supplemental irrigation water comes from two sources (well and surface water) an approved backflow prevention assembly should be installed between the irrigation well and surface water delivery system. An approved backflow prevention assembly is not required at the interconnection of a canal and a feeder irrigation ditch.

The WWLA operator must be familiar with pump discharge rates and the factors that affect discharge rates as described earlier. Knowledge of operating pressures in the field is crucial to understanding and evaluating water application flow rates and system efficiency. It is valuable to measure pressure at several locations, also known as pressure surveys. They are useful for identifying bottlenecks in the irrigation distribution system and can aid in designing system modifications or additions. Measuring pressure at the discharge point (sprinkler or gun) provides the most information about the actual rate of application.

Most guns have a fitting where a pressure gauge can be easily mounted. Rotary impact sprinklers can be fitted with a pressure gauge by installing a tee in the sprinkler riser. On an irrigation system or zone with multiple sprinklers, several pressure readings across the field give the best picture. However, at least one reading near midfield and one near the sprinklers installed at higher elevations provide valuable pressure information for the system. The pressure at the sprinkler head dictates the flow rate (gallons per minute) through that sprinkler. Significant elevation changes within one field or zone can result in higher discharge pressures and rates in the lower portions of the field.

Knowledge of pump pressure and field pressure can help the WWLA operator determine if pumps are running efficiently. An operating pressure that is less than the design pressure may indicate wearing of the pump or sprinklers. Gathering baseline data can also help determine when pipes are beginning to clog. Blockages, as well as broken or separated pipes, can cause pressure reductions in the distribution system. These problems often result in extremely wet areas that will be obvious to the WWLA operator. Wet and soggy areas near valves and fittings may indicate that the pipe has been damaged or improperly installed, such that leaks are causing the soil in the area to remain saturated.

Close monitoring of pumping rates by use of flowmeters or pump operating data will help with operational and maintenance decisions at the facility. Pump, piping, and sprinkler wear can be predicted with accurate flow records. These records can also help the WWLA operator determine if infiltration and inflow from the collection system are contributing to the recycled water stream. Accurate flow monitoring is important for compliance with state record keeping requirements, and may indicate when a system expansion is necessary.

If actual applied recycled water flows exceed the irrigation system design flow, then a detailed examination of the pumping and irrigation systems (sprinkler design and layout map) should be conducted and necessary steps should be taken to maintain compliance with the reuse permit.

Pump monitoring records, such as pump run time and number of pump cycles, can be used to monitor pump efficiency and proper working of float switches or relays. Following an inspection and maintenance schedule to identify and replace worn components will help a system to operate at its design flow.

In summary, the WWLA operator should maintain detailed records of all equipment and operational parameters at the facility. In conjunction with a detailed set of as-built plans, operational and maintenance decisions can be made to provide long equipment life and efficient overall system operation. Additional information regarding the operation and maintenance of land application equipment is presented in section 13.4.

11 Irrigation Systems Operations and Scheduling

Need-to-Know Criteria
Irrigation scheduling; basic soil-water relationships, estimating soil-water content, feel method, and checkbook method
Determining how much to irrigate; operational considerations
System calibration

This section discusses the operation and scheduling of the land application irrigation system. As discussed, land application facilities consist of many components, from the influent pipe to the soil-crop system, and everything in between. The WWLA operator must understand the entire system for it to perform properly. The WWLA operator does not need to be a specialist in all facets of land application system design, soil science, or crop science. However, the WWLA operator needs to understand day-to-day management and be able to identify those situations that call for technical assistance.

A main function of a land application system is to provide final treatment while protecting the quality of the land application environment. Another function is to provide beneficial reuse of the recycled water and nutrients to produce a crop. One way to minimize adverse environmental impacts at a land application site is to maintain a healthy system for final treatment. The WWLA operator must ensure that all aspects of the system are properly operated and maintained. Soil and crops must be protected so that continued use of the land application site is ensured. Surface and ground water must be protected to ensure the integrity of these resources. Sites must be protected from poor field operations that destroy soil structure. They must also be protected from overapplication of metals, nutrients, salts, and other constituents that can adversely affect the soil-crop system.

11.1 Irrigation Scheduling

Proper land application involves using water management strategies to ensure that water is applied at the proper time and in the correct amounts. This balance achieves the following:

- Optimizes the timing of nutrient application to match crop uptake
- Maintains adequate storage in the lagoon, if a lagoon is part of the land application system, to handle all inflows of water and precipitation without overtopping
- Applies recycled water at a rate and amount so that no direct surface runoff or deep percolation below the root zone occurs and provides the irrigation requirement for the crop throughout the growing season

The criteria listed above create an important framework for the operation and maintenance of a land application system. A responsible WWLA operator must understand how recycled water should be managed, have knowledge of the capacity of the system to store and apply recycled water when appropriate, and make prudent management decisions concerning when and how much recycled water to land apply. For a land application system, this decision-making process is called *irrigation scheduling.*

Irrigation scheduling is the process of answering two questions:

1. When to irrigate?
2. How much to irrigate?

Effective irrigation scheduling requires knowledge of soil properties, soil moisture content, crop type, climate, irrigation equipment, and estimated daily/weekly precipitation deficit. Monitoring soil moisture will help prevent runoff and leaching of recycled water (including nutrients) to the ground water. Monitoring soil moisture is important to ensure that land application of recycled water is conducted within permit limits. This section discusses the interaction of these factors and how to incorporate them into an effective irrigation schedule. Keep in mind that hydraulic and constituent loadings are established by the facility permit for both the growing and nongrowing seasons (if nongrowing season application is allowed in the permit) and should not be exceeded. The WWLA operator must comply with these permitted amounts when planning irrigation events. This section also focuses on irrigation scheduling for growing season operations.

11.1.1 Determining When to Irrigate

The following questions should be answered when deciding to irrigate:

1. Can the recycled water be applied to an actively growing crop (or will a crop be planted or actively start growing within 30 days)?
2. Is there a nutrient deficit remaining for this crop being grown?
3. Are the fields dry enough to be irrigated?

If the answer to all three questions above is *yes*, then an irrigation event should be scheduled. The answer to Question 1 should be obvious to the WWLA operator for growing season operations. Question 2 requires knowledge of the amount of nutrients that should be applied for the crop grown and the amount that has already been applied.

Determining the answer to Question 3, whether or not the field is *dry* enough to be irrigated, is not always obvious. Soil saturation can be determined by observing free water in an auger hole. However, other methods can determine whether a soil is saturated or not. If the soil is not saturated, the following methods can be used to determine how *dry* the soil is:

- A subjective method that involves *feeling* the soil
- Objective methods using soil-moisture measuring devices
- An accounting approach (checkbook method) to estimate soil-water content

11.1.2 Basic Soil-Water Relationships

Before attempting to measure or estimate soil-water content, recall the basic soil-water relationships discussed in section 6.4. Important terms to remember include *saturation*, *field capacity*, *wilting point*, *gravitational water*, and *plant-available water* (PAW).

Not all of the water added to soil is necessarily retained in the soil for use by plants. Water containing nutrients should be applied to soil so that the nutrients remain in the root zone for uptake by the crop. Water not retained in the root zone may transport constituents, resulting in a pollution threat to either surface water, ground water, or both.

To use soil-water measurements for irrigation scheduling, it is important to distinguish between two categories of soil-water:

1. Gravitational water—The water in the soil that is free to drain or move by the force of gravity. Gravitational water is computed as the volume of water in the soil between saturation and field capacity. When gravitational water is present in the root zone, the soil is *too wet* to be irrigated.
2. PAW—The amount of water held in the soil that is available to plants. It is computed as the difference between the water content at field capacity (referred to as upper limit water content) and the permanent wilting point (often referred to as the lower limit water content). Although water is theoretically available to plants between these two limits, if the soil water available to the plants falls below the maximum allowable depletion (MAD), there will be a loss in yield or crop quality due to moisture stress. Irrigation should be scheduled to maintain the water content of the soil above the MAD to avoid crop moisture stress losses. MAD is defined as the portion of PAW that can be used by the crop at specified stages of crop development that will not cause yield or quality loss due to moisture stress. If the soil-water content is above field capacity, gravitational water is present and irrigation should be delayed until the soil-water content nears the MAD under normal operating conditions. Figure 11-1 depicts the relationship between these soil-water terms.

Soil texture influences the portion of the soil pore volume that can be occupied by gravitational water or PAW; therefore, it is important to know the soil texture to determine how much water should be applied.

The amount of PAW that exists in the soil at any given time is commonly expressed as the depth of water per unit depth of soil. Typical units are inches of PAW per foot of soil depth. PAW, AWC in the root zone, can be estimated for various soil textural classes by using the United States Department of Agriculture, Soil Conservation Service, soil survey reports. Estimates are done by taking the AWC (inches of water per inch of soil) value and multiplying it by the total inches of soil root depth which will yield the number of inches of PAW for the soil root depth.

PAW values for various soil types may be compared to each other by calculating the PAW for a common soil depth, typically 1 foot. This can be done by multiplying the AWC (in inches of water per inch of soil) value by 12 inches per foot (in./ft), which will yield the number of inches of PAW per foot of soil. This basis of comparison estimates a range from less than 0.2 inch of PAW per foot of soil for coarse sandy soils to nearly 2 inches of PAW per foot of soil for silty clay and clay soils (Table 11-1).

At the start of irrigation, the water content in the soil should be at or lower (drier) than field capacity (upper limit). The difference between the existing water content and the field capacity water content is the maximum amount that should be irrigated. The drier the soil, the more water that can be safely applied per application, provided this amount does not exceed the required nutrient application rate or violate any other permit conditions. Determining the water content of the soil indicates whether the soil is dry enough to be irrigated and if so, how much water can be applied.

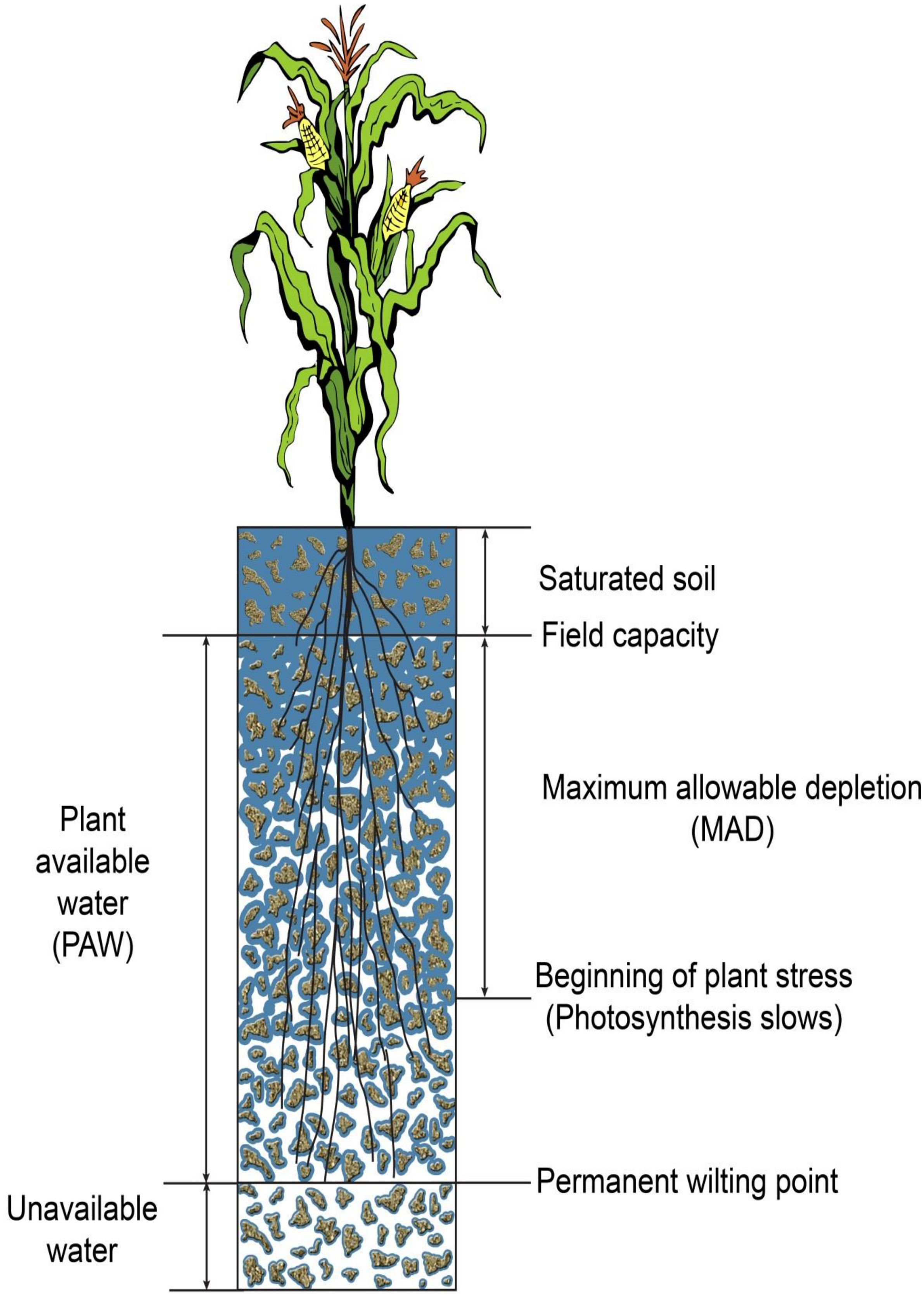

Figure 11-1. Soil-water relationships.

Table 11-1. Average estimated plant-available water for various soil texture classes.

Textural Class	Plant-Available Water	Maximum Recommended Application Depth
	inches of water per foot of soil	
Coarse sand and gravel	0.2 to 0.6	0.2
Sand	0.5 to 1.0	0.4
Loamy sand	0.8 to 1.5	0.6
Sandy loam	1.0 to 1.8	0.7
Loams	1.3 to 2.0	0.8
Silt loam	1.3 to 2.2	0.8
Silty clay loam	1.3 to 1.8	0.8
Clay loam	1.1 to 1.9	0.8
Sandy clay loam	1.1 to 1.8	0.8
Silty clay	1.2 to 1.9	0.8
Clay	1.2 to 1.9	0.8

11.1.3 Estimating Soil-Water Content

Three general methods are used for estimating the amount of water present in the soil:

1. Feel method
2. Soil moisture measurement devices
3. Checkbook method

One or more of these methods should be used to estimate the amount of water present in the soil before starting irrigation.

11.1.3.1 Feel Method

The feel method involves estimating soil-water content by feeling the soil. This method is a quick and simple method anyone can perform, and many WWLA operators schedule irrigation this way. This method is *subjective* because the results depend on the experience of the person doing the measurement. Therefore, the value of this method depends upon the experience of the WWLA operator. Guidelines for estimating soil-water content by the feel method are given in Table 11-2. Before using Table 11-2, reference Figure 6-5, which is the diagram for determining soil textural class by feel.

Use of the feel method is demonstrated in the following example. Suppose the irrigation field is a sandy loam soil with a 15-inch root zone. Feel the soil and observe that it forms a weak ball that falls apart. Based on the guidelines given in Table 11-2, you can irrigate 0.3 to 0.4 inches of water per foot of root zone depth. For a 15-inch (1.25 feet) root zone depth, the permissible irrigation amount is 0.38 to 0.5 inches:

- 0.3 in./ft x 1.25 ft = 0.38 inches
- 0.4 in./ft x 1.25 ft = 0.50 inches

Table 11-2. Recommended irrigation volumes, as a function of soil texture, based on estimates of plant-available water using the feel method.

Available Water Remaining in Soil	Sands Loamy Sand	Sandy Loam	Clay, Clay Loam, Sandy Clay Loam	All Other Textures
	Maximum Recommended Irrigation (per foot of effective root zone depth)			
100% (i.e., field capacity)	When ball is squeezed, no free water appears on soil, but wet outline of ball is left in hand.			
Irrigation	None	None	None	None
75% to 100%	Sticks together only slightly	Forms a ball that breaks easily	Forms a ball; very pliable	Easily ribbons between thumb and forefinger; feels slick
Irrigation	0.1 to 0.2 inches	0.2 to 0.3 inches	0.2 to 0.4 inches	0.2 to 0.4 inches
50% to 75%	Appears dry, will not form a ball	Forms a weak ball that falls apart	Forms ball; slightly plastic; slightly slick	Forms ball; forms ribbon
Irrigation	0.2 to 0.3 inches	0.3 to 0.4 inches	0.4 to 0.5 inches	0.3 to 0.6 inches
25% to 50%	Appears dry, will not form a ball	Appears dry, will not form a ball	Somewhat crumbly but holds under pressure	Forms ball under pressure; somewhat pliable
Irrigation	0.3 to 0.5 inches	0.3 to 0.6 inches	0.3 to 0.6 inches	0.3 to 0.7 inches
0 to 25%	Dry, loose, single-grained, flows through fingers	Dry, loose, flows through fingers	Powdery, dry; easily breaks into powdery conditions	Hard, cracked; may have loose crumbs on soil surface
Irrigation	0.3 to 0.5 inches	0.3 to 0.6 inches	0.3 to 0.7 inches	0.3 to 0.7 inches

11.1.3.2 Soil Moisture Measurement Devices

Another method for estimating the amount of water present in the soil is through the use of soil moisture measurement devices. These devices include the gravimetric method, tensiometer, electrical resistance blocks, neutron probe, Phene cell, electrical conductivity sensors, and time domain reflectometer. These devices differ in reliability, cost, and labor intensity. A general description of each device is given below.

11.1.3.3 Gravimetric Method

The gravimetric method is most accurate and useful for calibrating other devices that measure soil-water content. With this method, soil moisture is determined by taking a soil sample from the desired soil depth, weighing it, drying it in an oven (24 hours at 220°F), and then reweighing the dry sample to determine how much water was lost. This method is simple, reliable, and gives an accurate measurement of soil moisture, but it is not practical for scheduling irrigation because it takes a full day to dry the sample; in a sandy soil that dries quickly, irrigation may be needed before the results of the measurement are obtained.

11.1.3.4 Tensiometer

A tensiometer is a sealed, airtight, water-filled tube (barrel) with a porous tip on one end and a vacuum gauge on the other (Figure 11-2). A tensiometer measures soil-water suction (negative pressure), which is usually expressed as tension. This suction is equivalent to the force or energy that a plant must exert to extract water from the soil. The instrument must be installed properly, so that the porous tip is in good contact with the soil, ensuring that the soil-water suction is in equilibrium with the water suction in the tip. The suction force in the porous tip is transmitted through the water column inside the tube and displayed as a tension reading on the vacuum gauge. Soil-water tension is commonly expressed in units of *bars* or *centibars* (cb). One bar is equal to 100 cb.

The suction at the tip is transmitted to the vacuum gauge because of the cohesive forces between adjacent water molecules. As the suction approaches approximately 80 cb, the cohesive forces are exceeded by the suction, and the water molecules separate. When this occurs, air can enter the tube through the porous tip and the tensiometer no longer functions correctly. This condition is referred to as *breaking tension.* Tensiometers, therefore, work in the range from 0 to 80 cb. The suction scale on the vacuum gauge of most commercial tensiometers reads from 0 to 100 cb.

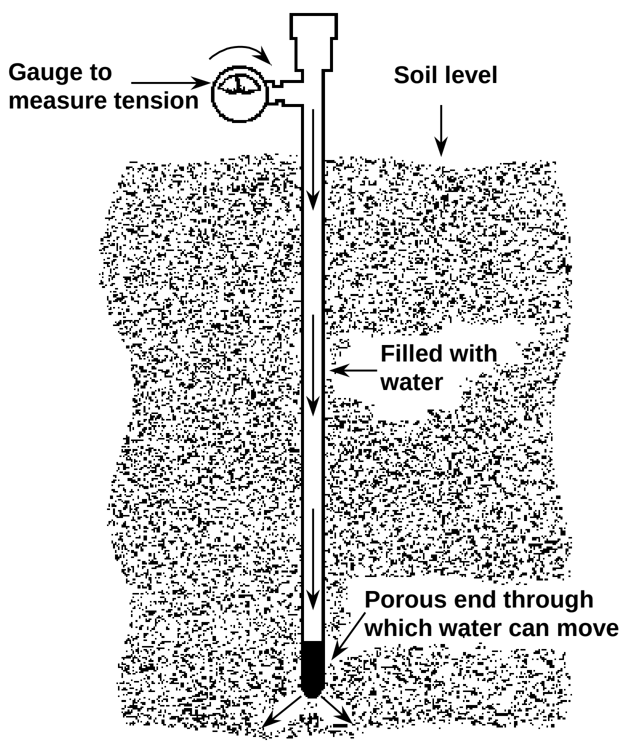

Figure 11-2. Tensiometer method of determining soil-water content.

Tensiometers are quite affordable compared to other soil moisture measuring equipment. The only other equipment required is a small hand-held vacuum pump used for calibration and periodic servicing. Tensiometers can be installed in a field and are easily maintained throughout the year.

Tensiometers are easy to use but may give faulty readings if they are not serviced regularly. They are best suited for use in soils that release most of their PAW at soil-water suctions between 0 and 80 cb. Soil textures in this category are those that consist of sand, loamy sand, sandy loam, and the coarser-textured range of loam and sandy clay loam.

Many clayey and silty soils still retain over 50% of their PAW at suctions greater than 80 cb, which is outside the working range of a tensiometer. Tensiometers are recommended for clayey and silty soils only if irrigation is to be scheduled before 50% depletion of the PAW, which is very common for many land application systems. It is also the normal practice for some vegetable crops such as tomatoes.

11.1.3.5 Electrical Resistance Blocks

Electrical resistance blocks consist of two electrodes enclosed in a block of porous material. The block is often made of gypsum, although fiberglass or nylon is sometimes used. Electrical resistance blocks are often referred to as *gypsum blocks* (or *moisture blocks*). The electrodes are connected to insulated lead wires that extend upward to the soil surface (Figure 11-3).

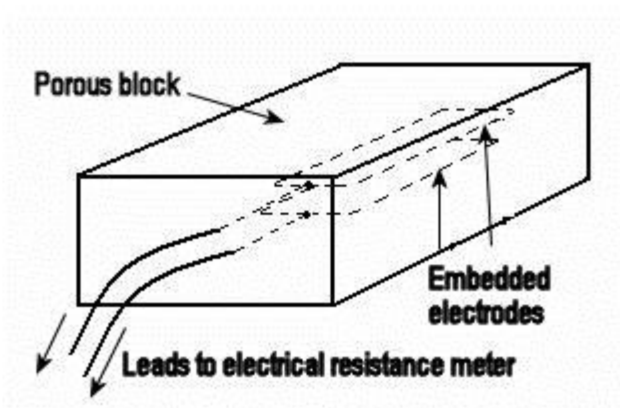

Figure 11-3. Electrical resistance block schematic (Hillel 1980).

Resistance blocks work on the principle that water conducts electricity. When properly installed, the water suction of the porous block is in equilibrium with the soil-water suction of the surrounding soil. As the soil moisture changes, the water content of the porous block also changes. The electrical resistance between the two electrodes increases as the water content of the porous block decreases. The block's resistance can be related to the water content of the soil by a calibration curve.

To make a soil-water reading, the lead wires are connected to a resistance meter containing a voltage source. The meter normally reads from 0 to 100 or 0 to 200. High readings on the scale (corresponding to low electrical resistance) indicate high levels of soil-water content, whereas low meter readings indicate low levels of soil moisture. Electrical resistance blocks are fairly inexpensive, costing from $5 to $30 each. A portable, hand-held resistance meter costs $180 to $400 and can be connected to read many different blocks in turn.

Because of the pore size of the material used in most electrical resistance blocks, particularly those made of gypsum, the water content, and thus the electrical resistance of the block, does not change dramatically at suctions less than 50 cb. Therefore, resistance blocks are best suited for use in fine-textured soils, such as silts and clays that retain at least 50% of their PAW at suctions greater than 50 cb. Electrical resistance blocks are not reliable for determining when to irrigate sandy soils, where over 50% of the PAW is usually depleted at suctions less than 50 cb.

11.1.3.6 Neutron Probe

The neutron probe uses a radiation source to measure soil-water content. An empty tube (*access tube*) with a 2-inch inside diameter must be installed vertically in the soil at each field location where the soil-water is to be measured (Figure 11-4). When properly calibrated, the neutron probe is easy to use, reliable, and accurate. Neutron probes can cost about $6,000 per unit.

One of the advantages of the neutron probe is that soil-water measurements can be made easily at different depths in the soil profile. Because of its cost, a neutron probe is not as practical as other methods, although it may be a viable option for WWLA operators with large acreages of irrigated land. At present, some irrigation consultants use neutron probes to perform the technical tasks required to schedule irrigation.

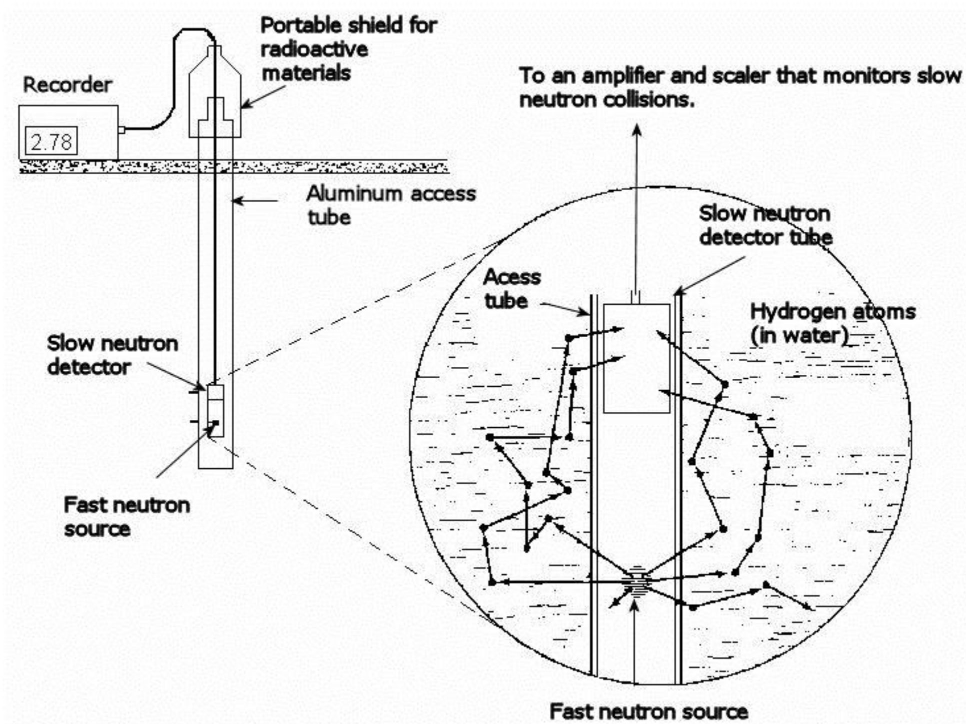

Figure 11-4. Neutron probe schematic (Brady 1990).

11.1.3.7 Phene Cell

The Phene cell works on the principle that soil conducts heat in relation to its water content. By measuring the heat conducted from a heat source and calibrating the conductance versus water content for a specific soil, the Phene cell can be used reliably to determine soil-water content. Because the Phene cell is placed at the desired soil depth, a separate cell is needed for each depth at each location to be monitored. A cell costs about $100, and the instrument required to measure the heat dissipation costs an additional $1,000.

For irrigating small acreages, the total cost of using the Phene cell is less than that of the neutron probe. For large acreages, the neutron probe may be more cost effective.

11.1.3.8 Time Domain Reflectometer

The *time domain reflectometer* is a device developed to measure soil-water content. Two parallel rods or stiff wires are inserted into the soil to the depth at which the average water content is desired. The rods are connected to an instrument that sends an electromagnetic pulse (or wave) of energy along the rods. The rate at which the wave of energy is conducted into the soil and reflected back to the soil surface is directly related to the average water content of the soil. One instrument can be used for hundreds of pairs of rods. The time domain reflectometer is easy to use and reliable, however, it costs around $8,000 per unit.

11.1.3.9 Selecting the Appropriate Device

In general, tensiometers and electrical resistance blocks offer the best combination of cost-effectiveness and reliability for measuring soil-water content. Tensiometers are best suited for sandy, sandy loam, and loamy soil textures, while electrical resistance blocks work best in silty or clayey soils. Manufacturers of these devices provide calibration charts and recommended ranges for traditional *fresh* water irrigation. Be aware that the calibration curves and recommendations supplied by the manufacturer for these devices were developed for general conditions and are not adequate for specific soil conditions and fields. Also be aware that recycled water objectives and recommendations are different from fresh water recommendations. For irrigating with recycled water, results are better if all soil-water measuring devices used are calibrated for the major soils you are irrigating.

11.1.3.10 Checkbook Method

The *checkbook method* is an accounting approach for estimating how much soil-water content remains in the effective root zone based on water inputs and outputs—like a daily balance on a bank account based on deposits and withdrawals. The inputs are the precipitation that is stored in the root zone and land-applied recycled water and the output is the amount of water used by the crops (this value is synonymous to *evapotranspiration* [ET]). Irrigation is scheduled when the soil-water content in the root zone drops below a threshold level.

The checkbook method requires detailed daily recordkeeping, which can become time consuming, but one of the advantages of the checkbook approach is that it can be programmed on a computer. Computer programs have been developed to handle the accounting and provide timely and precise scheduling recommendations. A simple spreadsheet can also be developed to handle the day-to-day calculations involved in this method.

To use the checkbook method, you must be able to estimate the rate that water stored in the soil is being used up. The University of Idaho extension office in Kimberly, Idaho, has developed a website that helps simplify determining the rate that water is used up in the soil. This site is called ET_{idaho} and can be accessed at *http://data.kimberly.uidaho.edu/ETIdaho/.* This site estimates the *precipitation deficit* (P_{def}) for various crops, which is equivalent to the ET minus the precipitation stored in the soil. With this information, the amount of land-applied recycled water can be determined.

Additional information can be obtained from the NRCS and National Weather Service.

To use the checkbook method, begin computations when the soil is at a known water content. Field capacity is the usual starting point and should be assumed to occur soon after a rainfall or irrigation of an amount large enough to wet the effective root zone. For many of the well-drained loamy soils found in Idaho (root zone textures consisting of loamy sand, sandy loam, loam, or sandy clay loam), field capacity can be assumed to occur 1 day after a rainfall or irrigation in excess of 1 inch. Example calculations for the checkbook method are shown in Table 11-3. The following information was used to set up this example:

- Soil—sandy loam
- Crop—alfalfa
- Effective root zone—As shown near the top of Table 11-4, the effective crop-rooting depth depends upon the stage of crop development. This example covers the first 5 weeks after crop emergence. For this stage of crop development, the effective rooting depth is 12 inches.
- Soil AWC value—0.14 inches water/inch soil (value found by consulting a soil survey report for the particular site location).
- PAW—AWC x Effective Root Zone = 0.14 x 12 = 1.68 inches
- MAD—Referring to Table 11-5, is the percent of PAW that can be used by the crop that will not induce moisture stress. Table 11-5 yields MAD = 5%. Because this is the maximum, irrigation should occur at or before 50%, when the PAW approaches 0.8 inches (0.5 x 1.68 inches).
- Growing season—For the assumed location, irrigation is recommended from May to October. Thus, the c*heckbook* begins on May 1.
- Conditions on May 1—The initial PAW may be estimated using the *feel* method. For this example, 0.27 inches of rainfall were received on May 1, and by using the feel method, it was determined that the soil was at field capacity at the end of the day (100% of PAW, 0 inch depletion).
- Daily P_{def} values—It is assumed that the WWLA operator collected daily P_{def} values from the ET_{idaho} Internet site.

Each day, a checkbook balance is computed based on additions (rainfall and/or irrigation) and removal (ET). It is assumed that this is a well-managed site without the removal routes of leaching or runoff. Leaching should be avoided to prevent contamination of the ground water. Runoff and potential ponding should be avoided to prevent plant mold and disease, odors, pests, vectors, and off-site runoff.

In the Table 11-3 example, irrigation events occurred on May 18, 25, and 29. Note that irrigation events could have occurred prior to these dates as long as field capacity values are not exceeded (%PAW values at the end of the day not greater that 100%). A full storage lagoon could be one reason for a facility to irrigate prior to reaching the maximum allowable depletion.

Table 11-3. Use of the checkbook method for irrigation scheduling soil-moisture balance sheet (modified from Ashley et al. 1998).

For Checkbook Irrigation Scheduling

Field ID _MU-0XXX01_ Crop _Alfalfa_ Emergence Date _May 1_

Stage of Development	Week After Emergence	Effective Crop-Rooting Depth at This Stage of Development (inches)	Water-Holding Capacity (AWC) per inch of Soil Depth	Water-Holding Capacity (AWC) in Root Zone, PAW (inches)	Allowable % of Available Soil Moisture to be Depleted from Root Zone (MAD)	Maintain Depletion Less Than (inches)
Stage 1	0-5	12	0.14	1.68	55	0.92
Stage 2	5-13	18	0.14	2.52	55	1.39
Stage 3	13+	36	0.14	5.04	55	2.77
Stage 4						

Week After Emergence/Stage of Development	Date	PAW[1] in soil at start of day		P_{def}	Irrigation	Leaching and run off	PAW in soil at end of day		Depletion	Comments
		Inches	% of PAW	Inches			inches	% of PAW	Inches	
Week 1	5-01	-	-	-	-	-	1.68	100	0.0	Assume field capacity is reached at the end of the first day based on feel method
	5-02	1.68	100	0.03	-	-	1.65	98	0.03	
	5-03	1.65	98	0.04	-	-	1.61	96	0.07	
	5-04	1.61	96	0.03	-	-	1.58	94	0.10	
	5-05	1.58	94	0.03	-	-	1.55	92	0.13	
	5-06	1.55	92	0.05	-	-	1.50	89	0.18	
	5-07	1.50	89	0.04	-	-	1.46	87	0.22	
Week 2	5-08	1.46	87	0.05	-	-	1.41	84	0.27	
	5-09	1.41	84	0.05	-	-	1.36	81	0.32	
	5-10	1.36	81	0.05	-	-	1.31	78	0.37	
	5-11	1.31	78	0.06	-	-	1.25	74	0.43	
	5-12	1.25	74	0.05	-	-	1.20	71	0.48	
	5-13	1.20	71	0.06	-	-	1.14	68	0.54	
	5-14	1.14	68	0.07	-	-	1.07	64	0.61	
Week 3	5-15	1.07	64	-0.04	-	-	1.11	66	0.57	
	5-16	1.11	66	0.06	-	-	1.05	63	0.63	
	5-17	1.05	63	0.07	-	-	0.98	58	0.70	Need to irrigate

	5-18	0.98	58	0.07	0.7	-	1.61	96	0.07	Irrigated 0.7 inch
	5-19	1.61	96	0.07	-	-	1.54	92	0.14	
	5-20	1.54	92	0.10	-	-	1.44	86	0.24	
	5-21	1.44	86	0.13	-	-	1.31	78	0.37	
Week 4	5-22	1.31	78	0.16	-	-	1.15	68	0.53	
	5-23	1.15	68	-0.01	-	-	1.16	69	0.52	
	5-24	1.16	69	0.17	-	-	0.99	59	0.69	Need to irrigate
	5-25	0.99	59	0.18	0.69	-	1.50	89	0.18	Irrigated 0.69 inch
	5-26	1.50	89	0.20	-	-	1.30	77	0.38	
	5-27	1.30	77	0.10	-	-	1.20	71	0.48	
	5-28	1.20	71	0.20	-	-	1.00	60	0.68	Need to irrigate
Week 5	5-29	1.00	60	0.19	0.68	-	1.49	89	0.19	Irrigated 0.68 inch
	5-30	1.49	89	0.24	-	-	1.25	74	0.43	
	5-31	1.25	74	-0.27	-	-	1.52	90	0.16	

Table 11-4. Seasonal crop-root zone development for specific growth stages.

Crop	Weeks After Emergence[a]	Stage of Development	Growth Stage Indicators	Total Depth of Effective Root Zone for Irrigation Water Management[b] (feet)
Alfalfa Established stands				4.0
New stand	0–5	Vegetative		0.5–1.0
	5–13	Vegetative		1.0–1.5
	13 to dormancy	Vegetative		1.0–3.0
Cereal grains, Spring	3	Haun Scale 1 to 3	Two leaves unfolded to four leaves unfolded (tillering)	0.5–1.0
	5	4 to 7	Five leaves unfolded to eight leaves unfolded	1.0–2.0
	6	8 to 11.6	Flag leaf through flowering	2.0–3.0
	8 to end of season	12 to 14.5	Milk development to soft dough	3.0–3.5
Cereal grains, Winter		Haun Scale 1 to 3	Two leaves unfolded to four leaves unfolded (tillering)	0.5–1.0
		4 to 7	Five leaves unfolded to eight leaves unfolded	1.0–2.0
		8 to 11.6	Flag leaf through Flowering	2.0–3.0
		12 to 14.5	Milk development to soft dough	3.0–3.5
Corn, field	2		Three leaf	0.6–1.0
	6		Twelve leaf	2.0
	8		Silking	3.0
	11		Blister kernel	3.5
Dry beans	2 to 3	V-4	Four leaf	0.8–1.0
	4.5 to 5.5	V-10	First flower	1.5
	6		First seed	2.0–2.5
Pasture				
Established				1.5–4.0
New stand	0–5	Vegetative		0.0–0.5
		Reproductive	Flowering	0.5–1.5
		Maturity	Mature seed	1.5–3.0

Potato[c]	4	I Vegetative Growth	Emergence to 8 to 12 leaves	0.66–1.0
	6	II Tuber Initiation	Tubers begin to form at tips of stolens	1.0–1.5
	14.5	III Tuber Growth	Early bulking to midbulking	1.5–2.0
	16.5 to 18	IV Maturation	Late bulking to maturity	2.0

a. Weeks after emergence is a less dependable means of estimating root development than growth stage indicators. Abnormal weather can delay or speed the rate of development.
b. Total depth of effective root zone for irrigation water management is reported for unrestricted root zones. Root zones may be restricted by physical (dry, water saturated, or compacted soils) or chemical (salt, sodic) factors. Root-zone calculations should be adjusted to account for restrictions.
c. Weeks after emergence for Russet Burbank. This time will vary with weather and variety.

Table 11-5. Percent of plant available soil water (PAW) that may be used without causing yield or quality losses (maximum allowable depletion).

Crop	Stage of Development	MAD[a] (%)
Alfalfa	All stages	55
Corn, field	All stages	50
Cereal grains	All stages except boot through flowering and ripening of wheat	55
	Boot through flowering	45
	Ripening (Wheat)	90
Dry beans	All stages	40
Pasture	All stages	50
Potato	All stages except vine kill	35
	Vine kill	50

(Modified from Doorenbos and Pruitt 1984)
a. Maximum allowable depletion (MAD)—Percent of available water that can be used by the crop at this particular stage of development that will not cause yield or quality loss due to moisture stress.

As discussed, soil-water content can be measured or computed by several different methods. WWLA operators should select the method that is appropriate for their site-specific soils and crops and one that the WWLA operator feels confident in using.

11.2 Determining How Much to Irrigate

For systems that do not have a *land-limiting constituent*, the amount of water that can or should be applied during any single irrigation cycle is dictated by the consumptive needs (hydraulic needs) of the soil-crop system. For sites with a land-limiting constituent (section 5.4.3), supplemental irrigation water is typically used to ensure the crop is receiving adequate moisture for crop health. The appropriate amount to irrigate varies from day to day and from season to season, as a result irrigation scheduling is influenced by the following:

- P_{def} (ET – effective rainfall)—When and how much, can be effected by temperature, wind, and relative humidity
- Crop maturity—ET/water uptake rate of the crop
- Soil moisture
- Effective root depth
- Availability of supplemental irrigation water

Recycled water or supplemental irrigation should replace the water that has evaporated from the soil or been removed by plants. As stated previously, PAW is the AWC of the soil in the root zone. The existence of bedrock, gravels, and hardpan layers can limit the maximum effective rooting depths to as little as 12 to 18 inches. It is within this depth that we estimate or measure the PAW deficit to be replaced by irrigation and/or precipitation.

Therefore, irrigation should be scheduled and timed so that the following applies:

- No surface ponding or runoff occurs during irrigation
- The root zone is not completely saturated at the conclusion of irrigation
- The irrigated water does not leach below the root zone

If the soil is at the permanent wilting point, the PAW deficit would be the entire PAW value for the given soil type (values shown in Table 11-1). In reality, the WWLA operator should never allow the soil to reach the permanent wilting point. Typically, the amount of soil water to be replaced will be less than the MAD (around 50% PAW) to avoid inducing moisture stress resulting in reduced yields. For example, Table 11-2 recommends water irrigation volumes based on estimates of PAW using the *feel* method.

Another factor affecting irrigation amount is the *soil infiltration rate*. As discussed in section 6.4.2, the infiltration rate is the maximum rate at which water enters the soil, typically expressed in inches per hour. PAW depletion and the soil infiltration rate are factors determining the amount of water that can be applied at the land application site at any given time. Infiltration rate is a function of the following:

- Soil texture
- Soil structure
- Soil moisture

- Vegetative cover
- Topography and landscape position

The infiltration rate decreases as more water is applied (increased soil moisture). The intake capacity of most clayey or silty soils begins to be exceeded by the time 0.5 to 0.6 inches have been applied. Continuing to irrigate could result in surface ponding and possible runoff. Infiltration rate also depends on the crop type and thickness of the stand and slope of the land. Typical ranges of infiltration rates for various soil textures are shown in Table 11-6.

Table 11-6. Approximate water infiltration rates for various soil textures and slopes.

	Slope		
	0 to 3%	**3% to 9%**	**9+%**
	inches per hour		
Sands	>1.00	>0.70	>0.50
Loamy sands	0.70 to 1.00	0.50 to 1.00	0.40 to 0.70
Sandy loams and fine sandy loams	0.50 to 1.00	0.40 to 0.70	0.30 to 0.50
Loams and silt loams	0.30 to 0.70	0.20 to 0.50	0.15 to 0.30
Sandy clay loams and silty clay loams	0.20 to 0.40	0.15 to 0.25	0.10 to 0.15
Clays, sandy clays, and silty clays	0.10 to 0.20	0.10 to 0.15	<0.10

Source: Sprinkler Irrigation Association Journal. For poor vegetative cover or surface soil conditions, actual rates may be as much as 50 percent less than shown.

Sandy soils have higher infiltration capacities and runoff is less of a concern. But, sandy soils also have lower PAW values. For example, consider a sandy soil that has a PAW value of 0.5 in./ft of soil depth. For a site with an effective root depth of 1.5 feet, the maximum PAW depletion is only 0.75 inches (Equation 11-1).

1.5 ft x 0.5 in PAW/ft = 0.75 inch PAW **Equation 11-1. Example calculation of PAW depletion.**

For this example, if the application amount during any single irrigation cycle exceeds 0.75 inches, some of the applied recycled water will leach below the root zone and potentially pollute ground water.

Taking all of the above factors into account, recommended recycled water irrigation amounts for a single irrigation cycle are in the range of 0.25 to 0.75 in./ft of effective root zone depth. Occasions may arise when the appropriate irrigation amount falls outside this range, such as when irrigation must occur during cold periods when ET is low, when the soil has an unusually deep root zone providing a greater amount of PAW storage, or to satisfy emergency action guidelines. But, these situations are exceptions and should not occur on a regular or frequent basis.

Regardless of the calculated rate, the system WWLA operator should monitor each application to verify adequate infiltration of the recycled water into the soil. An irrigation cycle should be stopped if ponding and/or runoff start to occur.

The typical permitted irrigation amount for the growing season is substantially at the *irrigation water requirement* (IWR). IWR is defined as any combination of precipitation, recycled water, and supplemental irrigation water applied at rates commensurate to the moisture requirements of the crop, and calculated monthly during the *growing season*. For good crop health and maximum yields, the WWLA operator should schedule irrigations so that the hydraulic-loading rate is as close to the IWR as possible. If the actual hydraulic-loading rate is below the IWR, crop health and yield will be reduced. In addition, irrigation at the IWR may not be feasible on soils with a high leaching potential. Overall supplemental irrigation may be used when the recycled water application does not satisfy the IWR.

Equation 11-2 is used to calculate the IWR:

$$IWR = P_{def} / E_i$$

Equation 11-2. Calculation of irrigation water requirement.

where:

P_{def} is the *precipitation deficit*. P_{def} is equal to the consumptive use of the crop minus the effective precipitation and is synonymous with the net irrigation requirement (IR_{net}). Values for P_{def} can be found for various locations around the state at the ET Idaho website : *http://data.kimberly.uidaho.edu/ETIdaho/*.

Ei is the *irrigation system efficiency*.

For permit purposes, the soil carry over moisture and leaching rate are assumed to be zero and, therefore, are not considered when calculating the IWR.

11.2.1 Operational Considerations

A key component of the irrigation design is to select the proper combination of system components so that the system irrigation rate does not exceed the infiltration rate of the soil. Knowledge of the system design is important for day-to-day irrigation scheduling.

Several terms may be used to express the rate at which water is being applied to a field during irrigation, including discharge rate and irrigation rate:

Discharge rate (flow rate) is the volume of water exiting a sprinkler per unit of time. Discharge rates are normally expressed in terms of gallons per minute (gpm). Manufacturers publish discharge rates for their sprinklers as a function of operating pressure and orifice diameter of the nozzle. Keep a copy of the manufacturer's discharge specifications for the sprinklers on your system. Discharge characteristics for three typical sprinklers used for wastewater irrigation are given in Table 11-7. For example, a Rainbird Model 70 sprinkler operated at 55 psi with a 9/32-inch diameter nozzle has a discharge rate of 17.2 gpm. Discharge characteristics for typical big guns are shown in Table 11-8. For contrast, notice how much higher discharge rates are for the gun sprinklers than for the rotary impact sprinklers.

In general, a larger nozzle with the same pressure creates an increased discharge rate, and a smaller nozzle with the same pressure creates a decreased discharge rate.

Additionally, changing pressures within sprinkler systems impact the wetted area, so increasing pressures increase the wetted diameter. Conversely decreasing pressures decrease the wetted diameter.

Table 11-7. Discharge characteristics for rotary impact sprinklers used with permanent stationary irrigation system.

Nozzle Size	Operating Pressure (PSI)					
(inch)	50		55		60	
	Flow GPM	Diameter FT	Flow GPM	Diameter FT	Flow GPM	Diameter FT
Nelson F70APV						
1/4	12.8	128	13.6	131	14.0	134
9/32	16.0	134	16.8	137	17.6	140
Rain Bird 70 CWH						
1/4	12.9	124	13.6	126	14.2	128
9/32	16.3	131	17.2	133	18.0	135
Senniger 7025 RD-1-DFF						
1/4	13.0	127	13.6	131	14.2	138
9/32	16.3	133	17.1	137	17.8	142

Irrigation rate is normally expressed as unit depth of water (inch) per unit of time, (usually an hour). The irrigation rate (inches per hour) depends upon discharge rate and coverage diameter. The irrigation rate (inches per hour) is computed by converting the discharge rate to a unit depth of water (inch) per unit time (hour), by dividing by the wetted area of the sprinkler.

Another important parameter is *total application depth* (inch), which is computed based on the amount of time the system operates at a given rate on a given field.

Table 11-8. General flow rates and coverage diameter for big gun sprinklers.

Taper Bore Nozzle										
	Gun Model									
	100T		**150T**		**150T**		**200T**		**200T**	
	Nozzle Diameter (inch)									
Pressure	0.5		0.75		1.0		1.5		2.00	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
50	50	205	115	260	205	310	—	—	—	—
60	55	215	126	275	225	325	515	430	912	512
70	60	225	137	290	245	340	555	450	980	528
80	64	235	146	300	260	355	590	470	1047	548
90	68	245	155	310	275	365	625	485	1105	568
100	72	255	164	320	290	375	660	500	1167	592
110	76	265	172	330	305	385	695	515	1220	607
120	—	—	180	340	320	395	725	530	1277	622
Ring Type Nozzle										
	Gun Model									
	100R		**150R**		**150R**		**200R**		**200R**	
	Nozzle Diameter (inch)									
Pressure	0.71		0.86		0.97		1.56		2.00	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
50	74	220	100	245	130	265	350	370	640	435
60	81	235	110	260	143	280	385	390	695	455
70	88	245	120	270	155	290	415	405	755	475
80	94	255	128	280	165	300	445	420	805	490
90	99	265	135	290	175	310	475	435	855	505
100	105	270	143	300	185	320	500	445	900	520
110	110	275	150	310	195	330	525	455	945	535
120	-	-	157	315	204	335	545	465	985	545

To attain acceptable application uniformity, stationary sprinklers are typically arranged in a square pattern, at a spacing of 50% to 65% of the wetted diameter. A typical layout for stationary sprinklers is shown in Figure 11-5. The orifice size, spacing, and operating pressure are selected from manufacturer's literature to achieve the adequate sprinkler overlap to ensure acceptable application uniformity.

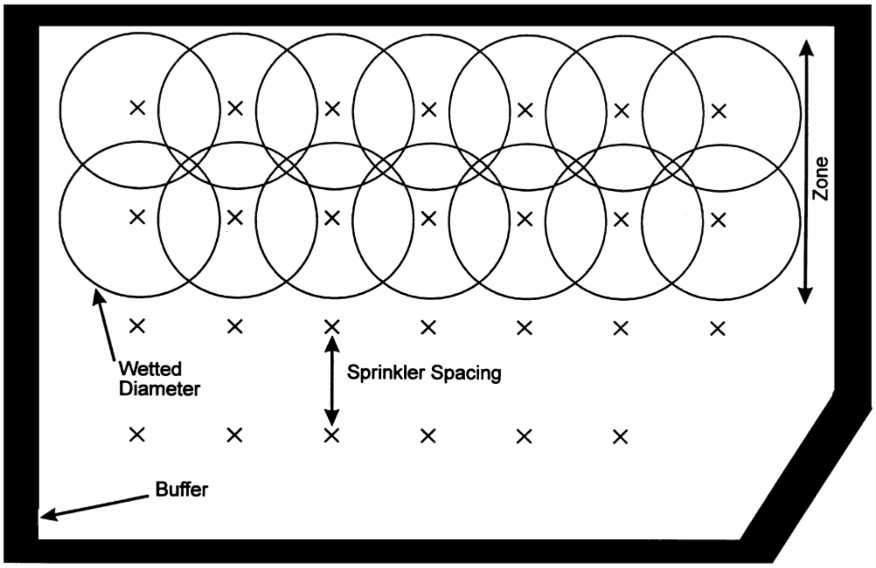

Figure 11-5. Typical layout of a stationary sprinkler system. Sprinkler spacing is typically 50% to 65% of wetted diameter.

11.2.2 Determination of Irrigation Rate for Stationary Sprinklers

The irrigation rate for stationary sprinklers can be computed using the formula of Equation 11-3.

$$\text{Irrigation rate (in/hr)} = \frac{96.3 * \text{discharge rate (gpm)}}{\text{sprinkle spacing (ft)} * \text{lateral spacing (ft)}}$$

Equation 11-3. Calculation of irrigation rate for stationary sprinklers.

11.2.2.1 Procedure for Computing Irrigation Rate

To determine the appropriate values to use in Equation 11-3, follow the procedure below:

1. Determine the discharge rate (sprinkler flow rate) and wetted diameter from the manufacturer's literature.

   Example: From Table 11-7, look up the values associated with the RainBird Model 70 sprinkler with a 9/32-inch diameter nozzle operated at 55 psi:
   - Discharge rate = 17.2 gpm
   - Wetted diameter = 133 feet
2. The recommended sprinkler spacing is 50% to 65% of wetted diameter. Using a value of 60%:
   - Design sprinkler spacing = 0.6 x 133 feet = 79.8 feet
   - Sprinklers are normally spaced in equal multiples of 20 feet based on typical pipe length. Therefore, the design spacing would be 80 feet (i.e., the sprinkler spacing

along the lateral would be 80 feet, and the lateral spacing would be 80 feet, so that the effective area of a sprinkler would be 80 x 80 feet).

3. The irrigation rate is then computed:

$$\text{Irrigation rate (in/hr)} = \frac{96.3 * 17.2\,\text{gpm}}{80\,\text{ft} * 80\,\text{ft}} = 0.26\,\text{in/hr}$$

   The irrigation rate of the sprinkler should be less than the infiltration rate of the soil, as given in Table 11-6.

4. Application depth is then computed as the irrigation rate multiplied by the operating time. In most cases, select the desired application depth based on one of the above methods. Compute the time required to operate the system to achieve the desired application depth. For example, if the required application depth is 0.6 inches, then the selected operating time for the system would be computed as follows:

$$\text{Time of Operation (hours)} = \frac{\text{target application depth (in)}}{\text{irrigation rate (in/hr)}}$$

   So,

$$\text{Time of Operation (hours)} = \frac{0.6\,\text{in}}{0.26\,\text{in/hr}} = 2.3\,\text{hours}$$

11.2.3 Center Pivot Systems

Center pivot systems come in a variety of designs and with many operational considerations. The newer models use a controller device that allows the WWLA operator to set and vary irrigation rates based on field variability or crop types over which the system is run. Since these systems can cover a large area, the sprinkler components are typically designed and installed for each individual situation. Therefore, no standard formula can determine the irrigation rate or travel speed for these systems. The manufacturer’s literature will explain the settings to achieve desired irrigation rates and volumes. Like any other type of irrigation equipment, it should be field calibrated periodically to verify that field irrigation rates are consistent with manufacturer’s design.

11.3 Equipment Calibration and Application Uniformity

Irrigation equipment must be calibrated based upon manufacturer’s recommendations and site conditions. Irrigation systems determine hydraulic and nutrient loading to the site so application uniformity is important. Application uniformity “describes how evenly an application system distributes water over a field”(James 1988).

Manufacturer’s specifications on irrigation equipment is usually based upon average operating conditions with relatively new equipment on flat ground with no wind. Discharge rates and irrigation rates change over time as equipment gets older and components wear. In particular, pump wear tends to reduce operating pressure and flow. With continued use, nozzle wear results in an increase in the nozzle opening.

When the nozzle opening changes (e.g., wear) from the original design, if nothing else changes, the discharge rate will increase and the pressure will decrease, which also decreases the wetted diameter. If system adjustments are made so that the pressure stays constant, then the increased opening will increase the flow and wetted diameter.

Be aware that operating the system differently than assumed in the design will alter the irrigation rate, coverage diameter, and subsequently the application uniformity. For example, operating the system with increased pressure, results in smaller droplets. The smaller droplets have greater potential for drift and odor. Additionally increased pressure increases the nozzle wear.

Clogged nozzles can result in pressure increase. Plugged intakes or crystallization of mainlines will reduce operating pressure. Operating below design pressure greatly reduces the coverage diameter and application uniformity.

Field calibrate the equipment on a regular basis to ensure proper irrigation rates and application uniformity. Field calibration for uniformity is recommended at least once every 3 years. Calibration involves collecting and measuring flow at several locations in the irrigation area. Any number of containers can be used to collect flow and determine the irrigation rate. Rain gauges work best because they already have a graduated scale from which to read the irrigation amount without having to perform additional calculations. However, pans, plastic buckets, jars, or anything with a uniform opening and cross section can be used if the liquid collected can be easily transferred to a scaled container for measuring.

For stationary sprinklers, collection containers should be located in a grid pattern throughout the irrigation area at several distances from sprinklers. Collection gauges should be spaced one-quarter the effective sprinkler spacing apart. For traveling guns, sprinklers should be located along a transect perpendicular to the direction of pull. Set out collection containers no further than 25 feet apart along the transect on both sides of the gun cart.

WWLA operators should compute the average irrigation rate for all collection containers and have the irrigation (or application) uniformity coefficient calculated for the system. The calculation of the uniformity coefficient is based on a complex calculation called the Christiansen calculation and is beyond the scope of this manual (procedures for calculating the uniformity coefficient can be found in the American Society of Agricultural Engineers standards (ASAE 1999). Ideally 100% uniformity is desirable but not practical, and typical values of uniformity range from 70% to 95%. A uniformity of less than 70% usually indicates system maintenance problems that need to be resolved. The WWLA operator can use the flow into each of the containers, described above, to determine how evenly the sprinkler system applies the water across the field. A deviation (more or less) from the average flow collected will tell the WWLA operator if a portion of the field is being underirrigated or overirrigated, which in either case will affect crop yield. Having a higher application uniformity will mean higher yields and a more profitable land application site.

Some of the maintenance problems that can contribute to low application uniformity are worn or plugged irrigation nozzles (measure for wear), a too high or too low system pressure, irregular rotation of the irrigation head, a sprinkler axis of rotation that is not vertical, and system leaks.

11.3.1 Summary of Irrigation Scheduling

This section has introduced a number of soil-water terms and irrigation formulas used to help determine how to properly apply wastewater. The use of these terms and formulas requires knowing the following items about the system and land application site:

- Soil types and infiltration rates by field
- Weekly, monthly, and annual irrigation depths
- Soil-water relationships and properties
- Acreage of each field to receive recycled water applications

Application equipment types and specifications include the following:

- Operating pressure
- Nozzle diameter
- Flow or delivery rate in gallons per minute per sprinkler
- Diameter of throw of sprinkler
- Travel speed settings for traveling equipment
- Number of sprinklers

With this information, WWLA operators can perform the calculations to properly develop an irrigation schedule for the land application system. With proper operation and maintenance, recycled water and any supplemental irrigation water may be applied to meet the moisture requirements of the soil-crop system while protecting the quality of the land application environment.

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12 Sampling

Need-to-Know Criteria
Sampling requirements, importance, number, and frequencies
Soil sampling
Plant tissue sampling
Ground water sampling
Minimizing contamination risks
Procedures for packing and shipping ground water samples

Sampling is important for proper operation of a land application site because the sample results tell the WWLA operator if the site is being managed properly and allows the WWLA operator to make informed decisions to avoid any possible adverse impacts to ground water, surface water, or public health. Most reuse permits require soil, plant tissue, recycled water, supplemental irrigation water, and ground water sampling and analyses. If such monitoring is required, the reuse permit will specify which parameters to monitor, when and how often to monitor, number of samples to be taken, and when results must be submitted. Although such sampling may not be required by every permit, all WWLA operators should have a basic understanding of the different types of analyses available, proper sampling techniques, and how to interpret analysis results.

12.1 Soil Sampling

The permit governs specific site sampling. Sampling procedures should be developed for each site and are usually found in the site facility QAPP. Each procedure should include information to ensure consistency from one sampling event to another, communication with the laboratory for proper methods, chain-of-custody procedures, and data handling for reporting purposes. Proper collection of samples and maintenance of sample analysis records is required by the permit. Additionally, the data from these samples should provide information to assist with efficient site operation and maintenance.

Soil sampling procedures should be in your QAPP, so follow your site QAPP. It is not possible to look at a soil and predict if it is too acidic or if there are proper amounts of the essential nutrients present. Soils in Idaho vary in their need for nutrients, depending on soil characteristics, previous fertilization levels, and nutrient requirements of the crop.

The goal of soil testing is to learn enough about the soil to provide economically and environmentally sound nutrient recommendations and to help evaluate the operation and management of the land application site. Soil testing provides an approach for WWLA operators to assess soil pH and plant-available nutrients, to determine the need for chemicals and fertilizers, and to avoid losses and environmental damage from improper practices.

The University of Idaho Cooperative Extension System Bulletin 704 on Soil Sampling provides information about collecting soil samples (Appendix F). For information on how to analyze soil samples, consult with the soil testing laboratory that will conduct the soil testing.

12.1.1 Soil Test

A soil test analysis is a chemical evaluation of the nutrient availability of the soil at the time of sampling. This is the nutrient supply available but is not a measurement of the plant-available nutrients because, as discussed in section 5, not all nutrients in the soil are in a form readily usable by plants. A goal of testing is to establish if there is nutrient overloading, enough nutrients, or nutrient deficiency. In deficient soils, nutrients needed for crops can be added as fertilizer.

Different methods may be used to sample soil, and understanding the reliability of each method is important.

12.1.2 Sampling Timing

Soils change through the seasons as water passing through the soils changes the nutrient contents available for crop uptake. Therefore, the timing of soil sampling should be close to planting and/or fertilization (recommended 2 to 4 weeks prior to fertilization or planting crops). Check with the laboratory well ahead of time for any special sample requirements including quantity, container types, turnaround time and specific analysis to be done. The reuse permit will establish the sampling minimum requirements for time and frequency.

12.1.3 Sampling Procedure

The permit governs specific site sampling. The site QAPP should incorporate the permit sampling requirements. The QAPP should consider that soil samples must be taken following a procedure that yields representative sampling of the site. The samples should be taken from representative areas, not from unusual areas such as fence lines or rock outcroppings. Generally, sampling equipment should be identified and constructed of materials that will not contaminate or react with the soils. Equipment should be clean and free of fertilizer and not made of galvanized iron or zinc coated. Fertilizer can create inaccurate results in the soil analysis. Test equipment made of galvanized iron or zinc could add zinc or iron into the sample. Depth of each sample must also be accounted for as nutrient levels in soil may be different in the different soil zones. The reuse permit will also establish the nutrients that must be sampled for and the depths of sampling.

Test methods should indicate a certain number of grab samples composted into a representative sample that is matched with the depth of the soil sample collected with the crop, tillage depth, and nutrients to be analyzed. The number of subsamples that should be taken to make a composite soil sample will be stated in the facility permit.

12.1.4 Using a Soil Test to Determine the Land-Limiting Nutrient

In situations where land application is limited by nutrients rather than by hydraulics, soil tests can be used to help determine the *land-limiting nutrient*. The land-limiting nutrient is the nutrient most likely to cause an adverse environmental or plant health effect if more is applied than the plants can use. Generally, nitrogen is the most common land-limiting nutrient, and application rates are based on supplying crop nitrogen (N) needs. The idea is to not apply nitrogen at rates greater than the crop can use because the nitrate form of nitrogen can move through the soil and threaten ground water quality.

12.2 Plant Tissue Sampling

The permit governs specific site sampling. The site QAPP should incorporate the permit sampling requirements. The QAPP should consider that plant samples must be taken following a procedure that yields representative as harvested samples. Healthy plants contain predictable concentrations of the essential elements. If these elements are not present in adequate amounts, then the plant suffers from a *nutrient deficiency*. In some cases, these nutrients are present in higher concentrations than required, and the plant may suffer from a *nutrient toxicity*. In either case, the plant is not healthy and is not efficiently removing nutrients from the soil. Plant tissue sampling can be used to distinguish between nutrient deficiency, nutrient sufficiency, and nutrient toxicity, which is an indication of crop health during the growing season (*crop management*). However, *crop uptake* determines nutrient removal from the land application site during harvest and is a permit requirement. Plant tissue sampling may be different depending on whether the information needed is to determine proper crop management for crop health or whether the information is needed to determine harvested crop uptake for permit compliance.

A recent soil test result can be helpful when interpreting plant tissue analysis. When visual symptoms of a suspected nutrient deficiency are present, take a soil sample at the same time from root zones of plants sampled. In this way, an evaluation of the soil in the affected area can be made along with an evaluation of the plant tissue. Sampling healthy and unhealthy plants, and their respective soil, is an effective crop management tool in determining optimum additions of plant nutrients to the soil (such as supplemental fertilizer). Taking some soil samples can help determine true harvested crop uptake for nitrogen in legumes, such as alfalfa, which has the ability to fix nitrogen from the atmosphere.

Plant analysis results can do the following:

- Indicate the nutritional status of plants (both crop management and crop uptake)
- Identify deficiencies and toxicities (crop management)
- Provide an accounting of nutrient utilization (crop uptake)
- Provide a mechanism for optimizing yield, quality, and efficiency (both crop management and crop uptake)

Plant analysis assesses nutrient uptake while soil testing predicts nutrient availability. The two tests are complementary as crop management tools, but each has limitations. Soil testing is not always a good indicator of nutrients such as nitrogen and sulfur that leach easily.

For crop management, a plant analysis may indicate that a nutrient deficiency or toxicity does not exist. Therefore, a factor other than nutrition may be responsible for poor plant growth or visual symptoms.

For crop uptake and permit compliance, plant tissue sampling is used to determine the amount of nutrients removed by the land application system. A sample of the harvested crop tissue is analyzed for nitrogen and phosphorus content to determine the amount removed from the field. Testing for ash may also be specified; ash results can be used to estimate the amount of TDS removed from the field.

If plant tissue monitoring is required by your system permit, the permit will specify which parameters to monitor, when to monitor, and when results must be submitted. However, additional sampling outside the permit may be needed for crop management analysis to determine crop health.

In the following subsections on plant tissue sampling, each subsection is divided into crop management or crop uptake to help the WWLA operator determine the type of sampling needed for each.

12.2.1 Taking a Representative Sample

Proper sampling is the key to reliable plant analysis results and required by permit. Sampling instructions, information sheets, and shipping envelopes are provided at no charge and can be obtained at the local Cooperative Extension Service.

When used for crop management, take samples from both *good* and *bad* areas. Comparison between the groups of samples helps pinpoint the limiting element. Comparative sampling also helps factor out the influence of drought stress, disease, or injury. Take matching soil samples from the root zones of both good and bad plants for the most complete evaluation.

When monitoring the status of healthy plants, take samples from a uniform area. If the entire field is uniform, one sample can represent a number of acres. If there are variations in soil type, topography, or crop history, take multiple samples so that each management area is represented by its own sample.

When monitoring for crop uptake of nutrients, take a sample that represents each harvested crop during each crop harvest/cutting. A representative sample is a composite sample of only the plant parts that are removed from the site. For alfalfa, a representative sample would be a composite sample of the entire harvested plant for each management unit. See Appendix G for more information on crop tissue sampling for crop uptake determination. Contact the analyzing lab for the appropriate sample size of crop tissue sampling for crop uptake determination.

12.2.2 Selecting the Best Indicator Sample for Crop Management

The appropriate part of the plant to sample varies with crop, stage of growth, and purpose of sampling. For mature plants, the *most recent mature leaf* (MRML) is the best indicator sample, except as noted in Table 12-1.

The MRML is the first fully expanded leaf below the growing point. It is neither dull from age nor shiny green from immaturity. For some crops, the MRML is a compound leaf.

Table 12-1. Situations in which the most recent mature leaf is not the best indicator sample.

Alfalfa, clover	Early growth through maturity—take top 2 to 3 inches of the plant
Corn	Bloom through maturity—take ear leaf
Small grain	Bloom through maturity—take the flag leaf
Turfgrass	Take clippings from mower bag

12.2.3 Choosing Sample Size for Crop Management

Laboratory analysis requires less than 1 gram of tissue, but a good sample contains enough leaves to represent a composite of the crop being managed. Therefore, the larger the area is, the larger the sample size needs to be.

Sample size also varies with crop. For crops with large leaves, a sample of three or four leaves is adequate. For crops with small leaves, a sample of 25 to 30 leaves is more appropriate. For most crops, 8 to 15 leaves is adequate.

12.2.4 Submitting the Sample

The following should be considered during sampling:

1. Use permanent ink or pencil on sample forms and envelopes. Tissue sample envelopes and information sheets are available from local Cooperative Extension Service.
2. Pay attention to detail when filling out the information sheet. Supply the information requested. Note any conditions—drought, disease, injury, pesticide, or foliar nutrient applications—that might be relevant.
3. When identifying the plants sampled, give the exact name, if possible. Give each sample a unique identifier that will help identify the plants or area to which it corresponds.
4. When sending matching soil, solution, or waste samples, indicate the matching sample identification on the forms. Be sure the grower's name and address are *exactly* the same on all matching information sheets.
5. Ship all matching samples in the same container.
6. Ship the tissue sample in a paper envelope or cardboard box, so it can begin drying during transport. Samples put in plastic bags will rot, and decomposition may alter test results.

12.3 Recycled Water Sampling

The permit governs specific site sampling. The site QAPP should incorporate the permit sampling requirements. Recycled water analysis is an efficient way to measure the levels of nutrients and other constituents in the land-applied water. Because the amounts of these constituents can vary among recycled water streams, laboratory analysis lets the WWLA operator know the proper amount of water to apply to meet the specific plant and general management needs for each site.

When management decisions are made without a water analysis information, even well-intentioned users can reduce plant growth and yields or endanger the environment. Typically, monthly sampling and analysis of the land-applied water is required in the reuse permit. The sample collection location and constituents to be analyzed are specified in the permit and vary between facilities, depending upon site characteristics and management practices.

WWLA operators who fail to test recycled water are faced with a number of questions they simply cannot answer:

- Are they supplying plants with adequate nutrients?
- Are they building up excess nutrients that may ultimately move to streams or ground water?
- Are they changing the soil pH to levels that will not support plant production?
- Are they applying heavy metals at levels that may be toxic to plants and permanently alter soil productivity?

Because environmental damage and losses in plant yield and quality often happen before visible plant symptoms, WWLA operators should always have the recycled water analyzed by a competent laboratory, and they are encouraged to have the application rates evaluated by a knowledgeable agronomist.

12.3.1 Recycled Water Sampling Terminology

The WWLA operator should be familiar with the following sampling terms:

- Grab sample—Collected over a period not exceeding 15 minutes. A grab sample is normally associated with water or wastewater sampling. However, soil and sediment may also be considered grab samples; no particular time limit would apply for the collection of such samples. Grab samples are used to characterize the medium at a particular instant in time and are always associated with instantaneous flow data, where appropriate. Grab sampling is conducted when the following is true:
  - The recycled water stream is not continuous.
  - The characteristics of the recycled water stream are known to be of consistent quality.
  - The sample is to be analyzed for parameters whose characteristics are likely to change significantly with time (e.g., dissolved gases and bacteria).
  - The sample is to be collected for analysis of a parameter where the compositing process could significantly affect the observed concentrations.
  - Data on maximum/minimum concentrations are desired for a continuous recycled water stream.
  - When the permit monitoring requirements specify grab sample collection.
- Composite sample—Used when average concentrations are of interest and are always associated with average flow data (where appropriate). Composite sampling is employed when the recycled water stream is continuous or it is necessary to calculate mass/unit time loadings or when analytical capabilities are limited. Many reuse permits require composite sampling of the land-applied water.
- Split sample—Portioned into two or more containers from a single container. Portioning assumes adequate mixing to ensure the split samples are, for all practical purposes, identical.
- Duplicate sample—Collected simultaneously from the same source, under identical conditions, and into separate containers.

- Control sample—Collected upstream or upgradient from a source or site to isolate the effects of the source or site on the particular medium being evaluated.
- Background sample—Collected from an area, water body, or site similar to the one being studied but located in an area known or thought to be free from effects resulting from reuse system operations. For example upgradient well water not impacted the site.
- Sample aliquot—Portion of a sample that is representative of the entire sample.

12.3.2 Sampling Procedures

Proper sampling is the key to reliable analysis results through a written procedure that was followed and documented. Although laboratory procedures can be extremely accurate, they have little value if the samples fail to represent actual conditions. The importance of careful sampling becomes clear when one recognizes that laboratory determinations are often made on a portion of the sample submitted that is as little as 0.02 pound, (1 gram) for solid materials, or less than a tablespoon (10 milliliters [mL]) for liquid materials.

Important considerations for obtaining representative recycled water samples may include the following:

- Sample locations taken from pipelines should be located where the stream will be well-mixed (turbulent conditions).
- For open flow channels, samples should be collected near the center of the flow channel, at a depth of approximately half the total depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Skimming the water surface or dragging the bottom should be avoided.
- When sampling from a mixing zone, cross-sectional sampling should be considered. Dye may be used as an aid in determining the most representative sampling points.
- For lagoons, the sampling method will depend on if the lagoon is well mixed or quiescent. For quiescent lagoons, it may require sampling at multiple depths and compositing to get a representative sample.
- Determine if the sample has special container requirements, temperature requirements and/or requires preservatives and make arrangements to have these items covered prior to going out in the field to obtain samples.
- Verify and collect the minimum amount of sample volume required by the laboratory.

12.4 Ground Water Sampling

Ground water monitoring is a standard requirement of most reuse permits to ensure that deterioration of ground water quality does not occur. One of the most critical parts of ground water monitoring is the sample collection process, which is discussed in the site QAPP. The permit site sampling requirements should be incorporated within the QAPP. Laboratories cannot compensate for a contaminated sample, and the sampling method is crucial for establishing permit compliance.

Note
For additional guidance on ground water well monitoring see the *Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater* (DEQ guidance) at *www.deq.idaho.gov/media/516329-guidance_reuse_0907.pdf*.

The following discussion concentrates on the most common ground water monitoring procedures for land application systems. It is beyond the scope of this manual to cover all of the types of monitoring systems and wells. However, no matter what type of well is being sampled, the procedures and important concepts covered should be followed consistently throughout the monitoring process.

If monitoring wells are required, a state-licensed engineer or hydrogeologist must prepare a report describing the depth of the ground water ("Well Construction Standards Rules" [IDAPA 37.03.09]) and must collect samples to establish background levels for the parameters of interest. This is usually done when the well has been drilled. As with other types of monitoring, the system's permit will specify what parameters to monitor, when to monitor, and when results must be submitted.

When reporting ground water monitoring data, describe the well location and use the monitoring serial numbers designated in the permit. In addition, identify each well as upgradient or downgradient in relation to the wastewater land application site. Upgradient wells are used for taking background water quality samples to determine the extent of ground water contamination by the land application site.

Information concerning proper ground water monitoring well location and construction is presented in section 7.5. Ground water sampling techniques are covered in this section and maintenance for monitoring well protection is described in section 13.4.

Ground water is sampled from specially designed wells that are carefully located. The wells must be sampled immediately after construction and then, if possible before land application begins—this determines background levels of constituents that are to be monitored. The system permit gives the frequency for all sampling based on facility and site conditions.

Before beginning compliance monitoring, complete the following:

- Determine the sampling schedule and parameters to be monitored as specified in the permit.
- Have a QAPP that covers ground water monitoring requirements.
- Select a laboratory that can meet the permit requirements.
- Provide the laboratory with a copy of the QAPP and monitoring requirements in the permit.

Prior planning and careful preparation of field equipment before sampling will ensure good results from the laboratory. Appendix H is a list of supplies and equipment to be used when sampling ground water.

12.4.1 Minimizing Contamination Risks

Minimize contamination risks while collecting samples:

- Ensure that all sampling equipment (e.g., bailers, tubing, and containers) has been thoroughly cleaned and selected based on compatibility with parameters to be monitored.
- Use Teflon, stainless steel, or glass when sampling for organics; do not use PVC or other plastics.
- Use Teflon or glass when sampling for trace metals.
- Use new sample containers when sampling for compliance monitoring; do not reuse containers.
- Keep containers closed before filling, and do not touch the inside of containers or caps.
- Wear a new pair of disposable gloves or decontaminated reusable gloves for each sampling site.
- Place new plastic sheeting on the ground near each well to hold the sampling equipment; do not step on the sheeting.
- Place small samples that require cooling, such as volatile organics, in sealable containers immediately after collection and before submerging in ice.
- Do not smoke while collecting or handling samples, because volatile residues in the smoke can cause sample contamination.
- Do not leave your vehicle running near the sample collection area to prevent contamination from engine exhaust fumes.
- If an internal combustion generator is used, set up the generator at least 15 feet away and downwind from the well; perform all generator maintenance and fueling off-site and away from samples.
- Avoid unnecessary handling of samples.
- If dedicated monitoring systems (those permanently installed in wells) are **not** used, clean equipment to be reused thoroughly before sampling each well to minimize the risk of cross contamination; bailers left in wells are **not** dedicated systems.
- Take enough precleaned equipment to the field to sample each well, so that cleaning between wells is unnecessary; if field cleaning is necessary, an equipment blank may be used to ensure that no contamination results.

Blanks should be used to check for contamination. Blanks consist of organic-free deionized water, which must be obtained from laboratories. Types of blanks include the following:

- A *trip blank* is a sealed container of organic-free, deionized water that must be taken to the field and sent back to the laboratory, unopened, with the samples; include at least one trip blank per cooler for volatiles to check for sample contamination during transportation.
- A *field blank* consists of organic-free deionized water taken to the field and handled in the same manner as the samples to check for contamination from handling, from added preservatives, or from airborne contaminants at the site, which are not from the waste being disposed of at the treatment facility.
- An *equipment blank* is organic-free deionized water, which is passed through the cleaned sampling equipment with added preservatives and is used to detect any contamination from equipment used for more than one well

12.4.2 Purging the Well

Before collecting any ground water samples, adequately remove stagnant water from the well by doing the following:

1. To purge a sufficient amount of water from a well, first calculate the well volume.
2. Based on the calculated well volume, pump or bail at least three well volumes from the well and/or until measurements for pH, specific conductance, and temperature meet the following conditions:
   - Two successive temperature values measured at least 5 minutes apart are within 1 °C of each other.
   - pH values for two successive measurements, measured at least 5 minutes apart, are within 0.2 units of each other.
   - Two successive specific conductance values, measured at least 5 minutes apart, are within 10% of each other.

This procedure will determine when the well is suitable for sampling for constituents required by the permit. Other procedures, such as low flow sampling, may be considered by DEQ for approval.

Following well recovery, samples may be collected using low rate pumping devices or a bailer. Dispose of purged water appropriately, according to state and federal regulations.

12.4.2.1 Purging with a Pump

Low rate pumping is the preferred method for purging because bailing may increase turbidity by stirring up sediment in the well. When purging with a pump, do the following:

- Slowly lower the pump to just below the top of the standing water column.
- Continue lowering it as the water level drops and the stagnant water is removed, as explained in section 12.4.2.

12.4.2.2 Purging with a Bailer

Using low flow pumps for purging generally produces high quality representative samples. However, if a pump is not available or cannot be used, use a bottom-emptying bailer to purge and collect samples. Bailer lines of braided nylon or cotton cord must not be reused, even if clean, to avoid the probability of cross contamination. Lines must consist of Teflon-coated wire, single-strand stainless steel wire, or other monofilament line.

Note
Do not leave bailers in wells. Contamination can occur when they are handled outside the wells and placed back inside. Contamination can also occur as a result of deterioration of bailer lines.

To purge using a bailer, do the following:

- Lower the bailer slowly, to just below the water level, and retract slowly to reduce aeration and turbidity.
- Collect the purged water in a graduated bucket to measure a minimum of at least three well volumes, or as discussed in section 12.4.2.

12.4.2.3 Collecting Samples

After wells are purged, collect samples using a low rate pump or a bottom-emptying bailer. Sample containers obtained from commercial laboratories or laboratory suppliers may already contain the appropriate preservatives. Check with the laboratory and follow their instructions.

12.4.2.4 Sampling with a Portable Pump

When sampling with a portable pump, do the following:

1. Lower the pump, slowly, to the desired depth in the well. (Have sample containers ready before turning on the pump.)
2. Adjust the flow rate to reduce agitation (generally this is less than 100 mL per minute).
3. Decontaminate the pump before moving to the next well.

12.4.2.5 Sampling with a Bailer

To collect a sample with a bailer, do the following:

1. Lower the bailer slowly into the well, avoiding agitation, and allow it to fill.
2. Retract the bailer slowly, and discharge the sample carefully into the container until the correct volume has been collected.
3. Add preservative if required, cap the container, and mix according to laboratory instructions. Take precautions to minimize agitation, which causes turbidity.
4. Use purging and sampling techniques previously described to minimize turbidity and agitation of sediment in wells.

In low-yielding wells and those containing high levels of suspended solids, slowly lower a bailer to the lowest standing water level and allow the water to flow into it. Carefully lift the bailer out of the well without allowing it to scrape or bang against the well casing.

12.4.2.6 Minimum Cleaning Techniques

Portable sampling systems are used more frequently than dedicated systems because of lower costs. However, because portable systems require using the same equipment from well to well, they increase the possibility of cross contamination unless strict cleaning procedures are followed. Cleaning procedures must be selected based on the equipment composition and the parameters to be monitored.

The following is a summary of minimum cleaning techniques for bailers, applicable for other equipment of the same composition. For stainless steel bailers and equipment, follow the cleaning technique steps below in order:

- Phosphate-free soap and hot tap water wash
- Hot tap water rinse
- Deionized water rinse
- Isopropyl alcohol rinse
- Deionized water rinse
- Air dry

Wrap the bailer with aluminum foil or other material to prevent contamination before use. Consider target contaminants when selecting a wrap material.

To clean Teflon or glass bailers and equipment, follow the cleaning technique steps below in order:

- Phosphate-free soap and hot tap water wash
- Hot tap water rinse
- Ten percent nitric acid rinse
- Deionized water rinse
- Isopropyl alcohol rinse
- Deionized water rinse
- Air dry

Wrap to prevent contamination before use. Again, consider the target contaminants when selecting wrapping material.

12.4.3 Procedures for Packing Ground Water Samples

At a minimum, the following should be done when packing samples prior to shipment by courier or by personal transport to the laboratory:

1. Line a clean cooler with a large heavy duty plastic bag and add bags of ice.
2. Place the properly tagged samples in individual, sealable plastic containers, and seal the containers with *chain-of-custody tape* to ensure sample integrity.
3. Place sample containers in the cooler, arranging bags of ice between samples to help prevent breakage; add sufficient ice to maintain the temperature at 4 °C (39.2^{o}F) while the samples are in transit.
4. Enclose the appropriate forms in a sealable plastic container, place with samples in the chest, and seal the large bag with chain-of-custody tape.
5. Minimize transport time and ensure that samples will reach the laboratory without being exposed to temperature variations and without exceeding holding times. Holding times typically are within 7 days of collection.

Once the laboratory has completed the sample analysis, a report containing the analytical results will be sent to the person requesting the analysis. Carefully fill out monitoring forms, ensuring that all information is included and that the data transferred from laboratory reports are recorded in the correct concentration units. Include complete identification information, such as permit number and facility, or permit name, on all correspondence and additional laboratory reports. Submit the forms and laboratory reports on time.

The WWLA operator is the critical link in the ground water sampling process. It is vitally important that the sampling procedures are followed carefully to avoid costly resampling and to ensure that any ground water contamination is quickly detected and remediated.

If the facility uses a contractor for ground water sampling, the WWLA operator should still be familiar with the sampling frequencies and parameters and the general requirements of the sampling protocol. Questions regarding monitoring requirements can be answered by contacting the appropriate DEQ regional office.

13 Site Operations and Maintenance

Need-to-Know Criteria
Soil management: ponding, runoff, surfacing, or prolonged saturation, surface crusting, and compaction
Crop management: crop selection, nutrient and physical management, pest control, best management practices, and troubleshooting
Management of recycled water application
Management of system components: maintenance procedures for leak detection, maintenance procedures for monitoring well protection, soil and site components, plan of operations, and records
Environmental protection and emergency action plans

The primary advantage of land application is the beneficial reuse of recycled water while protecting the quality of the land application site environment. The land application site serves as final treatment of the recycled water. WWLA operators must ensure that all aspects of the operation are addressed, including the following:

- Reconnaissance of the site by the WWLA operator is vitally important, not only in site selection but also to inspect the site for evidence of runoff and to collect samples and inspect crops.
- Soils and crops must be properly managed to ensure successful land application. One way to minimize adverse environmental impacts to the land application site is to maintain a healthy soil/crop system for final treatment.
- Ground and surface water must be protected to ensure the integrity of these resources.
- Sites must be protected from field operations that can impair soil structure. This could include soil compaction, erosion, or activities that cause unnecessary harm to crops.
- Sites must be protected from overapplication of metals, nutrients, salts, and other waste constituents that may adversely affect the soil-crop system.
- Adequate monitoring must be established to track the volume of applied recycled water and nutrients.
- Each facility should maintain a PO specific to that facility. The maintenance and management of the soils and crops at the facility should be specifically addressed in the manual, since the overall function of the system relies on these components.

This section presents guidelines for the operation, maintenance, and management of soil-crop systems and land application equipment. Areas addressed include the following:

- Soil management
- Crop management
- Management of recycled water application
- System component management
- Environmental management

13.1 Soil Management

A properly designed land application system should make maximum use of each soil-crop system on the site. Existing soil limitations must be addressed, either by limiting loading rates (e.g., hydraulic and nutrients) or by totally eliminating certain areas due to unsuitable soils or inadequate buffer zones. Factors that should be taken into account when selecting a site and designing a land application system include the following:

- Soil types
- Soil slope
- Crop type
- Crop health
- Recycled water application method, frequency, and irrigation patterns

Even when a site has been carefully selected and investigated, soil-related problems can arise. The following situations may indicate that a problem is soil-related:

- Seasonal ponding or surfacing of effluent, when recycled water application rates remain consistent
- Ground water compliance problems
- Problems in segregated areas of a field
- Effluent surfacing away from the land application field

If these problems exist, the WWLA operator should adjust recycled water application rates, in accordance with the methods described in section 11.

However, not all conditions can be remedied by such adjustments in operations. Some situations must be remedied by expansion of the land application site, which would involve a detailed soil and other site characteristic investigation, preparation of a permit modification application, and DEQ issuance of a new permit or a permit modification.

Recycled water application should be governed not only by weather conditions and soil moisture but also by the condition of the soil-crop system at the site. As the soil-crop system changes, application rates must change accordingly. Examples of changes that might occur in the soil-crop system include the following:

- Change of crops or management schemes
- Chronic saturation
- Buildup of thatch
- Presence of soil crusting
- Increased soil compaction
- Health of the crop
- Chemical changes in the soil

The soil-crop system must be carefully managed to avoid or minimize the following soil-related problems:

- Ponding, runoff, surfacing, or prolonged saturation
- Ground water mounding
- Surface crusting

- Compaction
- Excess nutrients

13.1.1 Ponding, Runoff, Surfacing, or Prolonged Saturation

One goal of land application is to apply recycled water at a rate that will result in neither runoff nor saturated flow conditions. This means that the water will slowly soak into the soil and be useful to the crop as both a water and nutrient source. Ponding, runoff, surfacing, or prolonged periods of saturation are undesirable. If mechanical causes for these problems are ruled out, a soil sample may determine if a soil condition exists that can be corrected.

Periodic wetness (soil saturation), runoff, or ponding of effluent are typically the result of hydraulic overapplication of water and can be controlled by applying water in accordance with levels acceptable by the soil-crop system. The fact that a given site is permitted for 30 inches of recycled water application per year is no guarantee that these application rates can be maintained every year or at all times during the year. Low areas that naturally receive more runoff must be loaded differently than areas on smooth upland positions, and effluent must be distributed to avoid localized ponding or overloading of a specific area. For example, if 30% of the spray nozzles are not working, the remaining portion of the field receives an increased volume of effluent. This localized hydraulic overloading may result in runoff (Figure 13-1), ponding, and/or insufficient treatment of recycled water in the soil-crop system. If runoff or ponding occurs, the operator should reduce the hydraulic-loading rate to levels acceptable by the soil-crop system.

Figure 13-1. Runoff from a land application site.

13.1.2 Ground Water Mounding

Even if recycled water soaks into the soil surface as desired, its downward movement may be impeded by a restrictive layer (a layer in the soil that reduces permeability, such as hardpan). If so, additional irrigation events can cause the subsurface saturated zone to rise in the soil, resulting in ground water mounding.

Depending on soil type, 1 to 3 feet of unsaturated soil are typically needed for recycled water treatment. If mounding results in saturated conditions within 3 feet of the soil surface, anaerobic conditions in the root zone can limit the growth potential of crops, resulting in insufficient treatment of recycled water because the water may flow laterally or surface at the ground.

The WWLA operator can readily check the level of a perched water table in fields or areas of concern:

- During times of expected high water levels in soils, an auger or posthole digger can be used to open a hole in the soil to the depth of interest. Usually, a hole 18 inches deep will be sufficient to indicate whether the soil surface is saturated.
- Sufficient time should be allowed for the soil water to move into the hole, generally an hour or so. If the water level is within 12 inches of the soil surface, water additions (rainfall or irrigation) may result in rapid lateral subsurface flow, ponding, anaerobic conditions for the crop roots, and potential for runoff or discharge of recycled water.

A more permanent monitoring device can be established by inserting a piece of perforated plastic pipe with a removable cap into the soil. This monitoring device should be marked, so it is not damaged by equipment, or set at grade level and marked with flagging or orange paint. Such simple devices can easily assist the WWLA operator in making irrigation decisions that protect the soil-crop system from saturation.

13.1.3 Surface Crusting

Poor management practices can result in surface crusting that forms a relatively impermeable layer at the soil surface. Such a layer can be created by excessive thatch, improper application of organic matter, and destruction of surface soil aggregates.

13.1.3.1 Surface Crusting Caused by Thatch

One cause of surface crusting that is often overlooked is the accumulation of thatch, which is a layer of dead and living grass shoots, stems, and roots. Excessive thatch buildup can result in reduced infiltrative capacity of the soil, acting as a barrier to added water. It can also serve to block the transfer of air (oxygen) to plant roots, causing further stress to the crop. In extreme conditions, anaerobic activity or algae growth can occur on the thatch buildup: an organic or slime layer may form a *clogging mat* and further decrease water infiltration. If a large enough portion of the site is affected, the result is increased load on the remainder of the site. For all these reasons, thatch buildup should be monitored and removed promptly if a problem is noted.

It is easier to prevent thatch buildup than to try to remove it. Prevention can be accomplished by frequent mowing, removing mowed vegetation, and operating the site so that wet conditions at the soil surface are not chronic. Thatch removal may be performed with special rakes or soil aeration tools. In extreme cases, disking the field or a complete replanting may be necessary. Since these activities result in significant damage or removal of the crop, some start-up time is required with a new crop, during which irrigation volumes must be reduced due to the potential of increased runoff and soil erosion.

13.1.3.2 Surface Crusting Caused by Improper Application of Organic Matter

As discussed, organic matter is found in most wastewaters. It may be in the form of large suspended solids, dissolved carbonaceous compounds, or both.

If improperly applied to the soil surface, suspended solids in recycled water may also generate a clogging mat, composed primarily of anaerobic bacteria, on the soil surface reducing infiltration into the soil, which may cause runoff or ponding. Once established, this slime limits the exchange of oxygen in the soil, and anaerobic conditions will develop under the soil surface. If these problems exist, collecting a soil sample may determine if the soil condition can be corrected.

Oxygen transport into and through the soil is critical for the degradation of organic additions. If recycled water is to receive sufficient treatment, it is essential that the soil drain adequately. Under waterlogged conditions, oxygen diffusion may be severely restricted. Sufficient time is needed for the oxygen to diffuse into the soil and for the microbial degradation to occur.

Hence, the irrigation frequency is quite important and organic overloading can occur if the above hydraulic-loading factors are not properly managed.

13.1.3.3 Soil Crusting Caused by Destruction of Surface Soil Aggregates

Soil crusting can also be caused by destruction of surface soil aggregates, especially when soil is exposed and left bare to heavy rains. High SAR or sodium in soils can also cause destruction of surface soil aggregates. Destruction of surface soil aggregates may result in fine soil particles. Fine soil particles disperse and seal the soil surface, which can become impermeable to infiltration if areas of bare soil occur at the land application site. Once soils become crusted, it can be difficult to establish plants or seedlings.

13.1.3.4 Dealing with Surface Crusting

In areas where crusting has occurred, it is important to restore aeration to the plant root zone and to provide favorable conditions for crops as well as for soil microorganisms involved in recycled water treatment. Surface crusting can be easily reversed by mechanical tillage to break up the soil surface or by raking to remove thatch.

However, because additional traffic increases the potential for compaction of subsurface layers, the crust should be broken using the lightest possible equipment, and the area must be reseeded. Any efforts to reestablish crops on areas of crusted soils or thatch buildup should be performed at the most ideal time for planting the crop that is to be used.

13.1.4 Compaction

As discussed in section 6.2.2, heavy traffic (especially on wet soils) can cause soil compaction, destroy soil pores, and reduce aeration and the effective permeability of the soil profile. Both surface and subsurface drainage and aeration are essential to maintain an aerobic soil environment suitable for recycled water treatment. The maintenance of a stable soil structure is an important means of maintaining good drainage and aeration. Therefore, traffic over a land application field should be limited to (1) equipment or vehicles that are absolutely necessary for operation and maintenance and (2) after soils have properly drained to avoid unnecessary compaction.

Once soil is compacted, tillage may be necessary. One of the principal objectives of tillage operations is to maintain or enhance the water infiltration capacity of the soil surface as well as the air exchange within the entire soil profile. It may be necessary to chisel very deeply (1.5 to 2.0 feet) to loosen the subsoil. Impermeable pans formed by vehicular traffic (plow pan) or by cementation of fine particles (hardpan) can be broken up by subsoiling equipment that leaves the surface undisturbed and protected by vegetation or stubble. To be effective, however, the subsoiling equipment must completely break through the pan layers. This is difficult if the pan layers are more than 1 foot thick.

Local soil conservation district personnel should be consulted regarding tillage practices appropriate for specific crops, soils, and terrain.

13.1.5 Excess Recycled Water Constituents

Monitoring the flow and constituent concentrations of the recycled water are typical requirements of a reuse permit, so the concentration of constituents in the recycled water and the expected volume should be analyzed prior to site evaluation to estimate potential land application area requirements. Metals, such as copper, zinc, and manganese, or other components, such as salts, pH, oils and grease, and organic and inorganic chemicals may prove to be limiting, depending on the site soils and the crops planted at the land application site.

Likewise, if the plant species is changed, recycled water characteristics must be assessed to determine if the selected plants are appropriate. When selecting crops, the amount of water that the crop needs for optimum growth must also be considered.

Significant levels of certain recycled water constituents may indicate the need for additional treatment prior to land application. It is beyond the scope of this manual to discuss all possible limitations that may be encountered with a land application site.

13.1.5.1 Excess Salts

The application of water containing soluble salts, such as chlorides, sulfates, potassium, calcium, manganese, and especially sodium, can be detrimental not only to the crops being grown on the site but to the soils as well. A buildup of sodium in the soil can reduce the permeability of the soil by causing dispersion of the clay minerals. Reduced permeability often results in poor internal soil drainage and aeration, which can cause stress to crops as well as ponding and waterlogged soils that do not provide adequate treatment. Municipal recycled water generally does not have high salts, however, industrial recycled water may be high in salt and salt loading should be managed.

It may be possible (but difficult) to renovate soils with high sodium concentrations. If the recycled water at your site has high salts, it is preferable to prevent the problem before it occurs by monitoring recycled water and soils for sodium and taking action before problems levels are reached. Salts can affect soil and vegetation in several ways:

- Adversely affect soil structure
- Upset soil-water balance and interfere with plant root growth, ability to take up water and nutrients, and reduce crop yields
- Leach to ground water
- Affect or reduce seed germination

The detrimental effects on plants result not only from the high salt contents but also from the level of sodium in the soil, especially in relation to levels of calcium and magnesium. To understand the management options to restore or prevent damage to the soil, the WWLA operator must first understand the difference between saline and sodic soils.

13.1.5.2 Saline Versus Sodic Soils

Saline soils contain concentrations of neutral soluble salts (such as sodium or potassium) sufficient to interfere with the growth of most plants. When large amounts of dissolved salts are brought into contact with a plant cell, water will pass by osmosis from the cell into the more concentrated salt solution. The cell then collapses, ultimately leading to cell death and eventually plant death.

Sodic soils, dominated by active sodium, exert a detrimental effect on plants in four ways:

1. Caustic influence of the high pH, induced by the formation of sodium carbonate and bicarbonate
2. Toxicity of the bicarbonate and other anions
3. The adverse effects of the active sodium ions on plant metabolism and nutrition and the low micronutrient availability due to high pH
4. Oxygen deficiency due to breakdown of soil structure in sodium-dominated soils

The influence of soil pH on land application activities is further discussed in section 6.3.4.

13.1.5.3 Plant Tolerance

Plant tolerance to saline and sodic soils depends on a number of interrelated factors, including the physiological constitution of the plant, its stage of growth, and its rooting habits. It is interesting to note that old alfalfa is more tolerant of salt-affected soils than young alfalfa, and that deep-rooted legumes show a greater resistance to such soils than the shallow-rooted ones (Brady and Weil 2008).

13.1.5.4 Evaluating Soils Conditions: Sodium Adsorption Ratio

To evaluate the condition of the soil, the nature of the various salts and their proportionate amounts, total concentration, and distribution in the soil profile must be considered. The structure of the soil and its drainage and aeration are important as well.

Prevention of the problem is very important. Once sodium and salt damage occurs to the soil, it is a slow and tedious procedure to restore the soil to its original condition. To prevent such damage, it is helpful to know the sodium concentration in the water.

As discussed in section 6.3.3, a ratio of the sodium concentration to the concentrations of calcium and magnesium is called the *sodium adsorption ratio* (SAR), and the value of this ratio is a good indicator of potential soil problems. For soils, the SAR test is run on a saturated paste extraction of the soil. The SAR test may also be run on a recycled water sample.

SARs in recycled water range from very low (less than 1) to several hundred. Industries that are especially prone to having SAR problems are the food processing industry, industries that use sodium hydroxide as a wash or disinfectant, or other operations using a form of sodium. *A SAR of 13 for a solution extract from a saturated soil paste is generally considered an upper level for safe operation*. However, many variables go along with the SAR that will determine if problems will be expressed in the soil.

At an SAR value of 10 or more, attention should be given to the sodium issue to ensure that future problems can be minimized and the WWLA operator should determine if excess sodium in the recycled water stream can be reduced. Soil samples should also be analyzed for SAR to help determine if the soil sodium activity level is approaching a problem level. Individuals with technical expertise should be contacted if the WWLA operator is not experienced with these issues.

13.1.5.5 Evaluating Soil Conditions: Exchangeable Sodium Percentage

Exchangeable sodium percentage (ESP) is another evaluation that can be used to determine possible excess sodium concentration in the soil itself. The ESP is the percentage of the soil's CEC that is occupied by the sodium cations. The ESP can be determined from a typical soil fertility evaluation (Equation 13-1).

$$\text{ESP} = \frac{\text{Na concentration}}{\text{CEC}} * 100\%$$

Equation 13-1. Calculating exchangeable sodium percentage.

An ESP level of *15% or higher is typically used to denote a level of concern (representative of sodic soils)*, where salt damage may occur both to the crop and to the soil structure resulting in loss of soil infiltration and recycled water ponding (an ESP level of 15 is approximately equal to an SAR of 13 for a solution extracted from a saturated soil paste) **(**Brady and Weil 2008). Due to the fact that SAR values are easier to obtain, the use of ESP has become less popular in recent years.

13.1.5.6 Evaluating Soil Conditions: Electrical Conductivity

Electrical conductivity is an indirect measure of soil salts. Pure water is a poor conductor of electricity, however, conductivity increases as salts are dissolved in water. Therefore, electrical conductivity is a measure of soil salinity. The most common method to determine electrical conductivity is saturation paste extract method and is the standard to which other methods are compared. Typically when determining soil structure or infiltration problems at a land application site, it is beneficial to look at both SAR and electrical conductivity. Table 13-1 lists typical water quality guidelines for recycled water that may have high salt concentrations.

Table 13-1. Water quality guidelines for irrigation.

Water Property	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity (affects crop water availability)				
EC_w	dS/m	< 0.7	0.7–3.0	> 3.0
TDS	mg/L	< 450	450–2,000	> 2,000
Physical Structure and Water Infiltration (evaluate using EC_w and SAR together)				
SAR = 0–3 and EC_w =	dS/m	> 0.7	0.7–0.2	< 0.2
SAR = 3–6 and EC_w =	dS/m	> 1.2	1.2–0.3	< 0.3
SAR = 6–12 and EC_w =	dS/m	> 1.9	1.9–0.5	< 0.5
SAR = 12–20 and EC_w =	dS/m	> 2.9	2.9–1.3	< 1.3
SAR = 20–40 and EC_w =	dS/m	> 5.0	5.0–2.9	< 2.9
Sodium (Na) Specific Ion Toxicity (affects sensitive crops)				
Surface irrigation	mmol/L	< 3	3–9	> 9
Sprinkler irrigation	mmol/L	< 3	> 3	—
Chloride (Cl) Specific Ion Toxicity (affects sensitive crops)				
Surface irrigation	mmol/L	< 4	4–10	>10
Sprinkler irrigation	mmol/L	< 3	> 3	—
Boron (B) Specific Ion Toxicity (affects sensitive crops)				
	mg/L	< 0.7	0.7–3.0	> 3.0

Source: Brady and Weil (2008)—modified from Abrol et al. (1988) with permission of the Food and Agriculture Organization of the United Nations.
Notes: EC_w = electrical conductivity of a solution extracted from a 1:2 soil-water mixture; TDS = total dissolved solids (TDS) milligram per liter (mg/L) can be converted to EC_w using these relationships: for sodium salts TDS = 640 X EC_w and for calcium salts TDS = 800 X EC_w); dS/m = deciSiemens per meter; and mmol/L = millimhos per liter

It is interesting to note that with regard to the effects on physical structure of soils, higher total salinity (EC_w) in the irrigation water compensates, somewhat, for increasing sodium hazards (SAR). In addition, while water low in salts (low EC_w) avoids problems of restricted water availability to plants, it may worsen soil physical properties, especially if SAR is high (Brady and Weil 2008).

13.1.5.7 Improving Productivity of Saline and Sodic Soils

Three kinds of general management practices have been used to maintain or improve the productivity of saline and sodic soils:

1. Flushing of the salts
2. Conversion of some of the salts to harmless forms
3. Designated tolerance

In the first two methods, an attempt is made to eliminate some of the salts or to render them less toxic. In the third, the salts concentrations are not manipulated; rather, crops tolerant of high salt concentrations are grown. These practices are described in more detail below:

- Flushing (salt removal)—The most common methods used to free the soil of excess salts are installation of drainage systems and leaching or flushing. A combination of flooding after field drainage ditches have been installed is often the best method. The salts that dissolve are leached from the soil profile and drained away. However, the irrigation water used must not be high in soluble salts, especially sodium.

Note
If a facility is considering this method, it is important to contact DEQ to discuss the proposal in detail. The facility may need to request an exception to the hydraulic-loading rate limits set forth in the permit. Any request for an exception must still achieve the objectives of protecting public health and preserving the beneficial uses of surface and ground water.

- Conversion—The use of gypsum on sodic soils is commonly recommended for the purpose of exchanging Ca^{2+} for Na^{+} on the clay surface and removing bicarbonates from the soil solution. Several tons of gypsum per acre are usually necessary. The soil must be kept moist to hasten the reaction, and the gypsum should be thoroughly mixed into the surface by cultivation, not simply plowed under. The treatment must be supplemented later by a thorough leaching of the soil with low-salt irrigation water to leach out some of the sodium sulfate.

Note
As with flushing, a facility considering this method should contact DEQ to discuss the proposal in detail.

- Tolerance—The use of salt-resistant crops is another important management tool. Although salt-tolerant crops are not considered *traditional* recipients of recycled water, many of the crops are high in value and could have the added advantage of income for a facility. For example, cotton, sorghum, barley, rye, sweet clover, and alfalfa are particularly tolerant. A crop such as alfalfa, once it is growing vigorously, may maintain itself in spite of increased salt concentrations in the soil that may develop later. The root action of tolerant plants is exceptionally helpful in improving the condition of sodic soils. Aggregation is improved and root channels are left, through which water and oxygen can penetrate the soil. Table 13-2 lists forage grasses and legumes and their various levels of salt-tolerance.

Table 13-2. Salt tolerance of forage grasses and legumes[a] (Bernstein 1958).

Good salt tolerance, 12 to 6 millimhos/cm	
Alkali sacaton	Rescuegrass
Barley	Rhodesgrass
Bermudagrass	Saltgrass
Birdsfoot trefoil	Tall fescue
Canada wildrye	Tall wheatgrass
Nuttall alkaligrass	Western wheatgrass
Moderate salt tolerance, 6 to 3 millimhos/cm	
Alfalfa	Perennial ryegrass
Beardless wildrye	Reed canarygrass
Big trefoil	Rye
Blue grama	Smooth bromegrass
Dallisgrass	Sour clover
Hardinggrass	Strawberry clover
Hubam clover	Sudangrass
Meadow fescue	Tall meadow oatgrass
Milkvetch, cicer	Wheat
Mountain bromegrass	White sweetclover
Oats	Yellow sweetclover
Orchardgrass	
Poor salt tolerance, 3 to 2 millimhos/cm	
Common white clover	Red clover
Meadow foxtail	Ladino clover
Alsike clover	Burnet

a. Within each category, the species are ranked in order of decreasing salt tolerance. The low in a higher category may be the only marginally better than the high in the next lower category.

13.1.5.8 Excess Oil and Grease

Oils and grease are organic compounds, and in concentrations typically seen in domestic wastewater, they pose no problem to the soil organisms that ultimately break down the organic compounds. However, significant inputs of oil and grease can cause problems in a land application system, both with equipment operation and the soil-crop environment. If oils and grease are allowed to build up in the soil, the result is the clogging of soil pores to the extent that infiltration of water and air into the soil are reduced. This results in stress to the crop as well as increased potential for ponding and runoff. If oil and grease exceeds 50 mg/L, then a process for oil and grease separation should be used to pretreat the land-applied recycled water.

13.2 Crop Management

Crops are useful in protecting soil, water, and the environment. The majority of crops are forages, such as grasses. These crops are dense and grow close to the ground, providing a cover above the soil surface and a fibrous root system below the surface that accomplishes the following:

- Results in better soil health, water-holding capacity, CEC, and soil microorganism populations, including earthworms, rhizobia, and bacteria

- Reduces the impact of raindrops on the soil surface, decreasing soil crusting, water runoff, and movement of soil particles off site, thus less movement of fertilizer and pesticides into streams
- Extends the amount and depth of root exploration of the soil volume, which indirectly relates to plant water use and nutrient uptake

Establishing and maintaining vegetative cover should be one of the highest priorities of the WWLA operator. The WWLA operator should routinely examine the health of the vegetative cover and take immediate action if there is a problem. Prevention is generally easier than remediation when it comes to plant health. Once plants begin to show stress, the problem is often well established and may require significant time and effort to correct.

Crops can be stressed by excessive water or by a lack of sufficient water. As discussed earlier in this section, crops can be stressed by excessive nutrient or salt applications. Conversely, crops can be stressed or damaged by insufficient plant nutrients or improper soil pH. Other factors include soil compaction and damage by maintenance equipment. The WWLA operator must be aware of the requirements of the crops and attempt to meet these requirements with a crop management plan. Such a plan will minimize the potential that the crops will be the limiting factor for system operation (Figure 13-2).

Figure 13-2. Poor crop stand in a fescue pasture. The lighter areas indicate stunted or dying vegetation.

Maintaining good crop growing conditions will reduce both surface runoff losses and subsurface losses of plant nutrients and will allow the recycled water system to perform as designed. Crop management involves the following activities:

- Crop selection
- Nutrient and irrigation management
- Soil fertility management

- Pest control
- BMPs
- Troubleshooting

13.2.1 Crop Selection

Important factors in the selection of crops for land application systems include the following:

- Nutrient requirements of the crops
- Time and length of the growing season
- End use of the crop
- Crop management requirements
- Water tolerance of the crop
- Use of seasonal overseeds
- Soil type
- Local climate conditions
- Using trees as a crop

13.2.1.1 Nutrient Requirements

The nutrient requirements of a crop impact system operation in terms of expense and time. If crops can be economically grown for harvest, such as in a commercial farming setting, and if the use of supplemental fertilizers is appropriate for the site, the time and cost expended fertilizing crops can be justified. Some crops are more tolerant of nutrient imbalances than others, but all crops will need some attention to maintain the health of the plants and ensure proper system operation. In selecting crops, consult an agricultural manual that shows crop nutrient needs and timing during the growing season. Table 13-3 lists general nitrogen fertilization guidelines for various forage crops.

Table 13-3. Nitrogen fertilization guidelines (Zublena et al. 1996).

Commodity	PAN /RYE[1]
Corn (silage)	10-20 lb N/ton
Bermudagrass (hay[2,3])	40-50 lb N/dry ton
Tall fescue (hay[2,3])	40-50 lb N/dry ton
Orchardgrass (hay[2,3])	40-50 lb N/dry ton
Small grain (hay[2,3])	50-60 lb N/dry ton
Sorghum—sudangrass (hay[2,3])	45-55 lb N/dry ton
Millet (hay[2,3])	45-55 lb N/dry ton

[1]PAN=plant-available nitrogen. RYE=realistic yield estimate.
[2]Annual maintenance guidelines.
[3]Reduce nitrogen rate by 25 to 30 percent when grazing.

13.2.1.2 Growing Season Time and Length

Ideally, the crops grown should be selected to fit the times when recycled water is generated and application is required. A mixture of crop types may offer the WWLA operator flexibility in system management.

13.2.1.3 Crop End Use

To keep a cropping system viable, it must be harvested at regular intervals. If there is no end use for the crop, less attention may be given to the crop's needs, possibly resulting in poor system management. Therefore, having a use for the crop should be a goal of the permittee and WWLA operator. If forage crops are mowed and baled, and simply left in the field to rot, the nutrients are returned back to the site and not removed. Hay bales can be sold for use as mulch or livestock feed. Compost can be made for use by the public. Crops with higher cash value can simply be sold as is. Wood products have infrequent harvest intervals, but a market should be planned for if those products are selected for use at the site.

13.2.1.4 Crop Management Requirements

Crops should be selected with a good understanding of their maintenance requirements. Is the crop perennial, or must it be replanted every year or two? Does it require multiple harvests during the year? Does the crop require nutrient applications two times per year or eight times per year? Are there other tedious tasks that need to be performed in order for the crop to stay healthy?

Generally, the simpler the maintenance scheme for a crop, the better it can be managed.

13.2.1.5 Crop Water Tolerance

A crop that cannot tolerate the expected combination of applied recycled water and precipitation at the site should not be used. Crop water tolerance may be a consideration in the wetter parts of the state such as northern Idaho. Some crops cannot tolerate soil saturation for very long, while other crops and grasses may even thrive in such conditions. Examples of crops, grasses, and trees that are especially water-tolerant include reed canary grass, ryegrass, common Bermuda grass, tall fescue, sweetgum, sycamore, and bald cypress. Examples of crops that are very susceptible to soil wetness problems include alfalfa and corn.

13.2.1.6 Seasonal Overseed Use

Forage grasses can be classified as cool season or warm season. No grass crop covers both categories.

Cool season grasses grow actively in the spring and fall. They may go dormant in the summer. Warm season grasses grow actively from mid-April through October 1 and are dormant through the winter.

If these seasonal crops are used, other grasses may be used temporarily as an *overseed* to help with nutrient uptake. For example, winter rye (a cool season grass) can be used as an overseed with Bermuda grass. Some forage species are not tolerant of this arrangement, and an overseeded species may seriously damage the main crop. Examples of grasses, forages, or grains that should be avoided as an overseed include gama grass, switch grass, or bluestems.

13.2.1.7 Soil Type

The crop selected must be adapted to the soil types on the site. On a large site, it is likely that several soil types exist; therefore, it may be necessary to use several crop types. Soils with heavy clay will stay wet longer after irrigation and rainfall events, and the crops must be able to handle these conditions. Sandy soils do not hold water and nutrients; therefore, a drought-tolerant crop will survive better, and split applications of fertilizer may be needed.

13.2.1.8 Local Climatic Conditions

The crop must also be adapted to the local area. Sometimes, crops are selected for their nutrient removal ability or ability to withstand wet conditions, but they may not tolerate the soils or climate. All factors must be considered when selecting a crop that can adapt to the site and recycled water applications and can be managed efficiently.

13.2.1.9 Using Trees as Crops

Using trees as crops at land application sites is increasing in popularity. Application of recycled water to forestland offers a viable alternative for the beneficial reuse of nutrients, and other constituents, while producing marketable wood products.

Under short rotations, trees can be whole-tree harvested, removing the nutrients from the site in a nonfood chain product. Under medium to longer rotations, high value solid-wood products, such as lumber or veneer can be grown.

Crop possibilities include ornamental trees and shrubs (ball and burlap) grown for 3 to 6 years and removed as thinnings or as an entire crop. For harvested tree crops, a second rotation will result from *coppice* (sprouts) from the existing root systems. Coppicing will result in intermediate tree cover and a continuance of vegetative cover on the site without replanting.

Phosphorus uptake in trees also compares favorably to high yield grass crops. Prior to using recycled water for tree irrigation, a silvicultural plan (a plan covering the care and cultivation of the trees) is prepared by a qualified silviculturist and is reviewed and approved by DEQ.

13.2.2 Nutrient and Irrigation Management

Once a crop has been selected, it must be established and properly managed to ensure that the crop thrives and functions as an efficient component of the treatment system:

- Crops should be planted at the best possible time. Time of planting is important because the survival rate of developing seedlings is related to the time at which stress occurs from drought, freezing, or competition for light and nutrients. If no such stress occurs, or if it occurs after seedlings are well established, survival and production losses can be minimized.
- Although many of the nutrients required by crops can be supplied through recycled water application, recycled water may not supply all the necessary plant nutrients. Nutrient application rates and application timing must be appropriate for the selected crop. Receiver crops vary in their ability to use nutrients. In systems where the water has high

concentrations of nutrients, nutrients may limit the application rates. Systems that are nutrient limited should time application events to appropriate stages in plant growth.

- WWLA operators must understand the agricultural operations and schedule their recycled water application to allow for events (e.g., harvesting and grazing) during which no water can be applied to a site.
- Sampling to assist in nutrient management decisions is recommended even if not required by the system permit. Table 13-4 describes rates and timing of nitrogen applications for optimum uptake by various crops.

Table 13-4. Nitrogen rates and timing of recycled water application to minimize soil leaching losses and luxury consumption by forage plants (Green and Mueller 1996).

Forage type	Typcial Annual Yield Range (tons/A)	Pounds of PAN N per Ton of Yield	Timing of Applications
Bermudagrass			
All pasture	4-5	30-40	At green-up in mid April, thereafter at 3 to 5 week intervals until Sept. 15
All hay or silage	5-8	40-50	At green-up in mid April, thereafter at 4 to 5 week intervals until Sept. 15
Pasture + overseeded	5-6	30-40	For bermudagrass same as above. For rye, Oct. and Feb. with rye in Sept. or Oct.
Fescue			
All pasture	2-4	30-40	1/3 Feb. 15-28; 1/3 April 1-15; 1/3 Sept. 1-15.
All hay or silage	3-5	40-50	1/3 Feb 15-28; 1/3 after first cut; 1/3 in Sept.

Crops must be managed to reduce soil erosion and nutrient losses. Perennial grass sods are particularly effective in this regard. When a field has a thick perennial cover, there is far less runoff, and therefore, less chance for fertilizers to be washed away. In addition, most perennial grasses form dense root systems, which effectively serve as filters to remove contaminants before they can seep into the ground water. Even if a given field is used for row crop production, forages may be used in conjunction to reduce erosion. Grassed waterways, grassed terraces, strip cropping, and long-term rotations using forages are good examples.

The soil-crop system completes the beneficial reuse of recycled water. Nutrients and other constituents supplied to the crops through recycled water application are incorporated into plant tissue. Therefore, it is important that the crop and its nutrients be removed through harvest. The soil can store some nutrients and metals, but its capacity is limited. Removal of the crop and its stored nutrients is essential. Otherwise, nutrients are returned to the soil as crop residues. Failure to remove the crop can lead to excessive nutrient levels on the site, potential plant toxicity, and potential surface water or ground water contamination.

13.2.3 Pest Control

Crops must be periodically scouted for pests. A discussion of all possible pests on all crops that may be grown on land application sites is beyond the scope of this manual, but resource guides and technical experts with USDA and the local Cooperative Extension Service can assist with this problem.

Any individual responsible for purchasing and applying restricted pesticides must be licensed by the State of Idaho. Restricted use pesticides must be used in accordance with label directions, and only licensed applicators can apply certain restricted use products.

Pesticides in ground water may result from spills or backsiphoning that can occur when pesticides are mixed or loaded. These problems present *point sources*, or small areas of high concentrations of pesticides that can contaminate large areas of ground water over time. Point source contamination can be located and cleaned up.

Good construction and maintenance of the pesticide mixing and loading area can prevent most of these problems, but pesticides may also be making their way into ground water from fields where they are applied. Applied pesticides can leach or move through the soil with water as it percolates down to ground water. The likelihood of a pesticide moving downward depends largely on its solubility, or its ability to dissolve in water. If a pesticide is highly soluble, it is more likely to reach the ground water. On the other hand, many pesticides, even some that are soluble, are likely to stick to soil particles by adsorption. Thus, if the probability of adsorption is high, less of the pesticides will leach.

Proper management of pesticides should be practiced to protect our water supplies. When applying pesticides, make sure that it is not a restricted pesticide. A restricted pesticide requires a licensed applicator. If applying a nonrestricted pesticide do the following:

- Read container labels correctly.
- Use the lowest effective rate listed on the label for any one application; the assumption that "if a little will do a little good, a lot will do a lot of good" is a fallacy.
- Correctly identify pests, so that you use the proper pesticide and do not wastefully apply inappropriate materials.
- Sweep small amounts of fertilizer or pesticide granules that may fall on impervious areas, such as sidewalks and driveways, into a vegetated area.
- Calibrate spreaders and sprayers, so that you know how much pesticide you are applying to an area.
- Learn about alternative pest control measures, such as beneficial insects, crop rotation, residue destruction, varietal resistance, proper planting dates, and companion cropping systems that may be good alternatives for your pest management problem.

For more information about pesticides application, contact the local Cooperative Extension Service.

13.2.4 Best Management Practices

A *best management practice* (BMP) can be any practice that reduces the movement of waste products (including odors) away from the land application site, and into ground or surface water or to other properties. BMPs are structural or operational practices that help to operate a land application system with the least chance of negative impacts on the environment. The most commonly used operational BMP to control runoff at a land application site is maintaining hydraulic-loading rates within levels acceptable by the soil-crop system. Crops and crop residues, cultural practices, and structures are used, alone or in combination, to hold the soil in place and allow water to move into it rather than to run off the surface.

BMPs relating to nutrient management are those practices that optimize nutrient uptake by plants and minimize nutrient impact on the environment. BMPs are site specific; a BMP in one place may not offer the same benefits in another location. Therefore, specific BMPs may or may not be mandated in regulatory documents. A trained agronomist or soil scientist is the best resource to assess whether a particular BMP is appropriate for your situation if it is not already included as a condition of the system permit.

BMPs at a land application site may include the following:

- Perform soil tests—Nutrients should be applied to soils only as necessary. To know the soil's nutrient-supplying capacity, have it analyzed by a soil test laboratory that uses testing procedures developed specifically for the soil conditions.
- Follow soil test recommendations—A soil test report indicates the amount of nutrients that the soil can supply and recommends the amount, if any, needed from other sources. The test also recommends appropriate amendments (such as lime or sulfur) to adjust soil pH to the proper range for the best crop growth. Soil deficiencies impact crops and deficiency of one nutrient or an undesirable soil pH will limit crop response to the other nutrients.
- Set realistic yield goals—All fertilizer recommendations assume a certain yield goal for the crop to be grown. Some laboratories ask for the goal, whereas others use an average number. The yield history of a field is the best guide to realistic expectations. Also, county soil surveys include crop yield estimates by soil series. Factors, such as the soil's moisture supplying capacity, should be considered.
- Do not overapply nutrients in the quest for unrealistic yields—Applying excessive amounts of nutrients can contribute to water pollution. For example, overapplying nitrogen is especially risky, since it can easily be lost from the soil.
- Apply nitrogen and phosphorus correctly—Nitrogen and phosphorus from fertilizer application are less likely to be lost by erosion or runoff if they are banded directly into the soil or applied to the soil surface and promptly mixed into the soil by disking, plowing, or rotary tilling. Subsurface banding also makes it possible for nutrients to be placed where the crop can make the best use of them.
- Do not apply nitrogen and phosphorus to soil surface without incorporation—This method is the least desirable way to apply fertilizer, but it is often used for pastures, lawns, turf, and other perennial crops. Because phosphorus is relatively immobile, phosphorus should be incorporated into the soil before perennial crops are established. Where surface application is unavoidable, minimize the use of phosphorus. Aeration equipment can be used to improve soil infiltration and nutrient movement into the soil. The application method (surface applied or banded) has little effect on losses of nitrogen by leaching.
- Time nitrogen applications appropriately—Application timing is more important with nitrogen than with any other nutrient. If nitrogen is applied in large amounts to crops the mobile nitrate form may move to ground water. Phosphorus, on the other hand, is more stable once it is mixed into the soil and can be applied when most convenient. Timing of nutrient application to coincide with plant growth requirements increases uptake efficiency and reduces exposure of applied nutrients to surface runoff and subsurface leaching. Optimum application time depends on crop type, climate, soil conditions, and

chemical formulation of the fertilizer. Fall application of nitrogen can result in surface and subsurface losses of nitrogen, especially on sandy soils.

- Control erosion—Nutrients can be lost when soil is eroded. For example phosphorus impact to surface water from erosion is of concern. With few exceptions, if no sediments leave the land, little phosphorus leaves. Many erosion-control BMPs can be used in various cropping systems. A conservation farm plan providing for erosion control should be developed with assistance from the NRCS, USDA, and local Cooperative Extension Service. Some specific practices include the following:
  - Maintain vegetation on ditch banks and in drainage channels—Try not to disturb vegetation in drainage channels such as ditches and sod waterways. If necessary, construct ditches larger than needed so the bottoms can be left vegetated to trap sediment and other possible pollutants. Seed ditch banks and prevent ditch bank erosion by proper sloping and by diversion of field runoff water.
  - Slope field roads toward the field and seed roads with a permanent grass cover—Water erosion and dust from traffic on field roads contribute significantly to soil loss and potential pollution. Do not plow field roads when preparing land. Shape roads for good drainage, and seed them with a perennial grass where possible. Direct field road runoff toward the field or into a sodded waterway and away from any bordering ditch or canal.
  - Shape and seed field edges to filter runoff as much as possible—Do not plow up to the edge of the field, especially along ditches or canals. Leave a buffer strip along drainage ways and establish a perennial sod. Shape and seed hoe drain outlets to filter runoff.
  - Use windbreaks and conservation tillage to control wind erosion—Wind erosion can be minimized by leaving the soil surface rough, maintaining crop residue on the soil surface, bedding to trap wind-blown sediments, keeping the soil wet, or maintaining a crop.
  - Maintain a soil cover—Leave crop residues on the soil surface during the winter. Do not till too early in the spring. Where feasible, use no-till methods, which may be the only way highly erodible land can be cropped without excessive soil loss. On soils that are subject to erosion or leaching, consider using a winter crop to reduce erosion and to take up nutrients, thereby reducing leaching. A crop used in this way is called a *trap crop*, since it *traps* and recycles nutrients for use by later crops.
  - Manage the soil for maximum water infiltration—Maintain crop residues on the soil surface. If little crop residue is left in the fall, establish a winter crop, but leave the soil surface rough enough to help trap recycled water. These goals can be accomplished by using high-residue crops in the rotation and by tilling carefully to prevent soil compaction.
- Manage nonrecycled water flows—Water management is closely related to erosion control, and some practices overlap. This section refers to water from precipitation and snowmelt, not to recycled water irrigation. In general, erosion is minimized when water flow is slowed or stopped. Some specific practices include the following:
  - Slow water flow—Use contour tillage, diversions, terraces, sediment ponds, and other methods to slow and trap rainfall and snowmelt runoff. The carrying capacity of running water is directly proportional to the flow rate. When water is still, sediments can settle out. Production practices, such as installing water-control structures (e.g.,

flashboard risers) on field ditches in poorly drained soils, benefit water quality significantly by reducing downstream sediment, phosphorus, and nitrogen. Sediment and associated phosphorus settle out of the drainage water, and nitrogen can be denitrified or used by stream vegetation.

- Preserve buffer strips—Leave buffer areas between fields and environmentally sensitive areas (Figure 13-3). The amount of buffer needed varies with the cropping activity and the nature of the adjacent area. Section 8.2 discusses buffer zones and the minimum buffer distances used in Idaho. Minimum buffer zones are typically specified in the facility's permit.

- Use appropriate crops—Deep-rooted crops, including alfalfa will scavenge nitrates that leach past the usual soil rooting zone. Used in crop rotation, following shallow-rooted or heavily fertilized row crops, deep-rooted crops will recover excess nitrate from the soil and reduce the amount of nitrate available for leaching to ground water.

Figure 13-3. Riparian buffer zones lining streambanks.

No single set of BMPs applies in all situations, but when properly carried out, BMPs can improve water quality. Many studies document water quality improvement in streams adjacent to where BMPs have been used in surrounding agricultural areas. If BMPs are not performing their functions as designed, contact a trained agronomist or soil scientist for advice on appropriate remedies.

13.2.5 Troubleshooting

Diagnosing the needs of plants is comparable in many ways to diagnosing human ills. The medical doctor observes the patient, obtains all the information possible with questions, and then makes the appropriate tests, all of which are helpful in diagnosing the case. Similarly, the

WWLA operator observes the plants, obtains information on past management, and may test the soil or the plant; the success of the diagnosis depends on the WWLA operator's understanding of the fundamentals of plant and soil science and on a correct interpretation of the test results.

Diagnostic measurements of the ailing plant or soil are often referred to as *troubleshooting*. Plant and soil samples can and are being used for troubleshooting, but a more important application is preventive measures. By the time a plant shows stress, it may be too late. To be proactive in crop management, become familiar with stress symptoms of plants.

Many of the methods for evaluating soil fertility are based on observations of, or measurements on, growing plants. These methods have considerable merit because the plants act as integrators of all growth factors (i.e., aeration, fertility, moisture, and pH) and are the products in which the WWLA operator is interested. Abnormal appearance of the growing plant may be caused by a deficiency of one or more nutrient elements (Figure 13-4).

If a plant is lacking in a particular element, characteristic symptoms may appear. This visual method of evaluating soil fertility is unique in that it requires no expensive or elaborate equipment and can be used as a supplement to other diagnostic techniques (typically the first indicator of poor crop health). Examples of stress symptoms are as follows:

- Complete crop failure at seedling stage
- Severe stunting of plants
- Specific leaf symptoms such as changes in coloration appearing at varying times during the season
- Delayed or abnormal maturity
- Obvious yield differences, with or without leaf symptoms
- Poor quality of crops
- Poor germination, resulting in reduced stand coverage

Figure 13-4. Sulfur deficiency in corn.

Be aware that in the field it is often difficult to distinguish among the causes of symptoms. Disease or insect damage frequently resembles certain micronutrient deficiencies; for example, leaf hopper damage is often confused with boron deficiency in alfalfa.

If symptoms are observed early and are correctly diagnosed, they might be corrected during the growing season. Crop health may suffer during the first year, but if the trouble is properly diagnosed, the symptoms may be fully corrected the following year.

If a crop is not present, or is in poor health, the WWLA operator should start the troubleshooting process. The following steps should be included when attempting to establish a crop or repair an existing crop:

1. Obtain a representative soil sample.
2. If the crop is present but in poor shape, obtain a plant tissue analysis.
3. Check the area to see if prolonged saturation or soil compaction is a problem.
4. Select a crop or combination of crops suitable for the soil and site conditions, and one that can be managed in a recycled water application environment.
5. Select a crop that can be used locally or that has some return value.
6. Apply recommended nutrients and/or pH adjustments from the soil test results.
7. Prepare to plant or seed the crop, following all recommendations from the supply store, or contact the local Cooperative Extension Service.
8. Implement BMPs recommended by a trained agronomist or soil scientist.

13.3 Management of Recycled Water Application

Runoff and/or ponding is a site condition that is typical of hydraulic overloading and can be avoided by maintaining the hydraulic-loading rate within the levels acceptable by the soil-crop system.

Irrigation scheduling recommendations discussed in section 11 should be followed.

13.3.1 Uniformity of Recycled Water Distribution

Uniform distribution of recycled water at the land application site is necessary to ensure that the entire land application site treats the recycled water and to minimize overloading of any particular area. The WWLA operator should be familiar with the design plans for the facility, including those design features that are intended to *not* apply water evenly across a field. These design features may be required due to changes in soil conditions, slopes, or nearby drainageways.

In other cases, a site may be designed to receive uniform application across an entire field. The WWLA operator, however, knows that the system cannot be operated on that field or area at a uniform application rate without runoff or ponding. Ultimately, the WWLA operator is responsible for operating the system within the requirements of the permit, which includes minimizing ponding and runoff.

Note
Any design modifications to the recycled water distribution system must be reviewed and approved by the DEQ.

13.3.1.1 Handling Bleed-off

Areas that are prone to wetness, or hydraulic overload include the heads of drainageways, soils with less permeable layers, compacted soil areas, areas with poor crops, and areas at the base of slopes. In most irrigation systems, a condition known as *bleed-off* is experienced when the WWLA operator ends an irrigation cycle. The water remaining in the distribution system will typically run to the lowest lateral and spray nozzle, and recycled water will trickle out of this nozzle, sometimes for many minutes before the distribution lines are clear. This condition can result in local overloading and the possibility of ponding or runoff.

The WWLA operator can account for bleed-off in one of two ways:

1. The irrigation cycle can be stopped early enough to anticipate the bleed-off and still have the soil in the bleed-off area absorb the effluent.
2. The WWLA operator can install hardware to stop or spread out the bleed-off condition to minimize any localized overload.

13.3.1.2 Handling Chronic Hydraulic Overload

An area that is continually overloaded hydraulically will soon be obvious to the WWLA operator. The crop in that area may be taller or greener than in surrounding areas. If the situation is very bad, the local area may exhibit signs of crop stress or death due to chronic saturation. Another problem with chronic saturation is that it will eventually break down the soil structure, making the area even less permeable than it originally was. Crop harvest or maintenance procedures may have to be delayed or ignored if wet spots in the field are a problem.

Actions to minimize the potential for hydraulic overload include the following:

- Change the nozzles in wet areas to nozzles that deliver less wastewater per unit time.
- Valve or cap individual risers so that they can be turned off to limit recycled water application or to reduce bleed-off.
- Valve individual lateral or manifold lines to reduce application.
- Use directional sprinklers to avoid slowly permeable areas or landscape positions.
- Use subsoiling equipment to revive the soil permeability.
- Enhance the soil infiltration rate with good crop management and conservation practices.

13.3.2 Winter Operation

Some land application systems operate throughout the winter months, while some systems operate exclusively during the warm growing season. During the winter, evaluate your system and its components and take the necessary precautions for freezing.

Note
For additional discussion of winterization of irrigation equipment, see Appendix I.

WWLA operators of systems that function through the winter must be aware of the effects of cold weather on land application operations. During cold weather operation, the WWLA operator should inspect the fields prior to any application events and verify that the entire field has thawed and can accept recycled water. Cold temperatures result in slower drying times, and therefore, reduced application depths, as discussed in section 11. The reduced depths may necessitate more frequent irrigation cycles of briefer durations when using a solid set or drip system and different settings on mobile units, such as center pivots.

If water is allowed to remain in the irrigation lines on very cold nights, problems with freezing and equipment damage can result. The vulnerable areas are the risers, exposed valve boxes, aboveground piping, and suction or discharge piping from the pump (if not protected in a pump house or underground pump vault). On mobile systems, gun carts and center pivot towers are vulnerable to freeze damage. Most irrigation risers are equipped with underground drain or weep holes that allow the water in the riser to soak into the soil after the pump has been turned off and the pressure in the line decreases, but the WWLA operator must ensure that any abovegrade valves are opened so that water is not trapped in the equipment.

Other units, such as center pivots, have caps or plugs that must be removed to allow drainage of the aboveground piping. Where aboveground piping is used, this pipe should be separated in several places, especially low areas, allowing water to drain from the pipe. Some units recommend purging some of the water with forced air; others do not require special freeze protection for the hose. All, however, require drainage of all fittings, turbines, and feed lines to protect the components and the warranty.

13.4 Management of System Components

The WWLA operator of a recycled water irrigation system must be familiar with the physical components that make up the system, understand how they work, and ensure a schedule of maintenance and troubleshooting actions to ensure proper operation of the system. This section focuses on the management of the following system components:

- Land application equipment
- Drainage systems
- Soil and site components
- Plan of operations
- Records

13.4.1 Land Application Equipment

An irrigation system is an expensive investment. Regular maintenance procedures will help keep the system operating properly for many years.

The original manufacturer’s operation and maintenance manual or instructions for operation for each piece of irrigation equipment should be the primary source of information that provides the minimum required maintenance. If the manual cannot be located, ask the local dealer or equipment manufacturer for a replacement.

Adherence to the routine maintenance procedures will also reduce the risk of equipment failures that may lead to lost production time and crop loss, or that could result in a discharge of recycled water and damage to the environment.

Appendix I contains an excellent publication that outlines the maintenance procedures for various types of land application equipment including the following:

- Annual maintenance procedures for sprinklers
- Lubrication and fluids schedule for hard-hose travelers
- Seasonal maintenance checklist for center-pivot and linear-move systems
- Weekly, quarterly, and annual maintenance requirements for pumps
- Inspection and maintenance schedule for electric motors that power irrigation pumps
- Inspection and maintenance schedule for diesel motors that power irrigation pumps
- Winterization and storage procedures for hard-hose travelers, center-pivot and linear-move systems, pumps, and engines that power pumps

13.4.1.1 Maintenance Procedures for Leak Detection

Localized chronic wet areas in a field, or along the piping to a field, can indicate a leak or break in the distribution network. Valve junction boxes are a common place to find leaks in the system. Leaks can be caused by freezing water in the lines or spray risers, damage from equipment, or failure of the part. Usually, a leak in the distribution system is easy to spot, as a chronic wet area, regardless of the amount of spraying. Not only could this lead to a violation due to ponding and/or runoff, but it also affects system performance, where flow has been reduced.

Rotating sprayheads can be another place for equipment damage or malfunction. A sprayhead that is stuck in one position can easily result in a large amount of water applied to a small area, soon resulting in runoff and/or ponding. Sprayheads should be monitored frequently for proper operation. Something as simple as a piece of trash can cause a small diameter sprayhead to clog or remain stuck in one position. Sprayheads should be cleaned and maintained regularly. Where rust or corrosion prevents proper operation, replacement may be the best option.

13.4.1.2 Maintenance Procedures for Monitoring Well Protection

The area around ground water monitoring wells must be protected:

- Highly visible markers may be used to warn equipment operators of the presence of the well.
- Using posts cemented into the ground to surround the well offers added protection against a well being hit with equipment.
- Slope area around well to promote drainage away from the well.
- Damage from equipment includes cracked grouting, cracked or broken well piping, or broken locks or casings. This type of damage can result in intrusion of surface water into the well and ground water contamination. The well may have to be abandoned and another well may need to be constructed, which results in additional time and expense.

Monitoring well maintenance includes ensuring that caps are rust-free and locked at all times, the outer casing is upright and undamaged, and a clear, unobstructed path exists leading to each well.

13.4.1.3 Maintenance Procedures for Flowmeters

Two important tools can assist the WWLA operator with irrigation scheduling. The first is a rain gauge (or set of gauges); the other is a well-calibrated flowmeter.

The flowmeter shows the volume of water that is being applied to the irrigation fields. Accurate flowmeter readings can consistently be obtained when the flowmeter is properly and frequently calibrated. Flowmeters must be regularly calibrated to the manufacturer's specifications. Using a flowmeter that has not been calibrated can create more problems than not having a flowmeter at all. Frequently, the dealer who sells the flowmeters has a specialist who can perform the calibration.

Flowmeters should be installed based upon manufacturer specifications and where the risk of corrosion from such devices as chlorinators or other chemical injection systems is minimized.

Flowmeters are beneficial for ongoing maintenance of a land application system:

- Flowmeter readings help with irrigation scheduling and overall operation.
- Consistent usage of a calibrated flowmeter is crucial in determining the amount of nutrients, salts, or other constituents that are being applied.
- Placement of a flowmeter on the influent side of the treatment system. Monitoring the influent flow shows if additional inputs are coming into the system. Additional inputs include illegal connections to the collection system, infiltration, or inflow.
- Increased flowmeter measurements in response to rainfall indicate there are leaks into the collection system that should be repaired. This issue is primarily with municipal sewers.

13.4.1.4 Maintenance Procedures for Plans and Specifications

The WWLA operator should have a set of system plans and specifications that specify all the equipment at the facility. These documents may specify the flow rate or application rate of the irrigation equipment being used. The specifications are only valid as long as the pump runs at a certain speed, the equipment is new, the valves are all in the appropriate position, and no changes are made to the system (such as adjusting valves or replacing sprayheads). Information presented in manufacturer's charts is typically based on average operating conditions with relatively new equipment.

13.4.1.5 Maintenance Procedures for Equipment Aging, Replacement, and Servicing

Discharge rates and application rates change over time as equipment gets older and components wear. In particular, pump wear tends to reduce operating pressure and flow. Nozzle wear results in an increase in the nozzle opening, which will increase the discharge rate while decreasing the wetted diameter. Extreme nozzle wear can result in pressure decreases substantial enough to affect sprinkler rotation. To ensure proper placement and rate of delivery, proper calibration of sprinkler equipment is necessary. Improper calibration and equipment maintenance will result in over or underapplication and uneven nutrient distribution. Equipment calibration is discussed in section 11. When replacing equipment, ensure that the replacement unit is adequate for the job. Replacement equipment must have the same rating and power requirements, so that it can be interchanged without affecting the overall functioning of the system.

All mechanical components will have some type of servicing requirements. Failure to perform regular maintenance results in equipment that does not last as long, and the possibility of premature failure during operation. Equipment failure at the wrong time could lead to a significant spill or leak, causing a permit violation and possible threat to the surrounding environment.

13.4.2 Drainage Systems

The WWLA operator needs to know if a separate surface water, ground water, or stormwater drainage system exists, either in the area being irrigated or the areas surrounding the land application site. Drainage can be a subsurface tile drainage system, surface ditching, or a combination of both. The operation of the land application system may depend on proper functioning of the drainage system; if such a drainage system exists, there should be references to it in the permit and in the design plans and specifications. Often a drainage system is used to divert surface water away from a land application site.

The permittee must identify if the WWLA operators are also responsible for ongoing operation and maintenance of a separate drainage system or if other employees are responsible for the drainage systems. Drainage systems also need periodic attention to ensure proper operation. If the WWLA operator is responsible for proper maintenance of the separate drainage system, then the following checklist will help keep the drainage system working properly to prevent adverse impacts to the nearby land application system:

- Mark all drainage outlets and check frequently to ensure the outlet is free of vegetation that could obstruct the outflow of water from the drainage system.
- Protect piped drainage outlets with animal guards to prevent stoppage from animals.
- Establish proper erosion control around the outlet to stabilize the drainage water and to ensure erosion does not damage the outlet area.

Erosion prevention can include the use of terraces and surface water diversions designed to divert surface water. These surface water diversions must be properly vegetated to minimize erosion caused by the moving water. Erosion can readily change the slope or grade of the structure and affect its operation. On the other hand, if a surface water terrace or diversion becomes filled with sediment and loses its depth, runoff water designed to be trapped in the diversion may eventually overtop the structure. The original design criteria for all such structures should be maintained on the site, and the structure should be periodically monitored to ensure that it is at or near design specifications. If necessary, remove sediment or repair eroded areas to keep the structure at design criteria.

Verify the drainage system is performing its function. After a soaking rainfall, inspect the outlets to ensure that the system is working. Any length of the drainage pipe can become clogged with sediment or broken by heavy equipment.

If the drainage system is not moving water as expected, inspect the entire system to look for places where clogs may have occurred. Evidence of clogs may appear as wet spots along the drainage lines. Subsurface drainage systems can fail when the pipe is crushed or if holes or breaks occur. Also, if the system does not have the proper grade for water flow, as can happen with uneven settling, problems occur with the drainage system working as designed. Uneven ground surface along the drain lines can also indicate a break in a subsurface piping network.

13.4.3 Soil and Site Components

To better accommodate recycled water and ensure proper treatment, consider expanding the site if you experience one or more of the problems:

- Saturated soils

- Ponding or runoff
- Excessive hydraulic-loading rates
- Excessive constituent-loading rates
- Crop stress due to excess soil moisture
- Inability to maintain storage or freeboard in a lagoon, pond, or storage tank

Before expanding the site, however, first determine that the chronic wet conditions are not a result of excess infiltration and inflow into the collection system or a correctable soil-related condition (section 13.1). If the chronic wet conditions are due to a high water table, quit using that field for reuse.

13.5 Recordkeeping

Recordkeeping is required by the reuse permit. System operation and performance is enhanced by good recordkeeping. Maintaining records helps ensure that all permit conditions are met, equipment is maintained at necessary intervals, and the WWLA operator can make prudent land application decisions. Good recordkeeping can help the WWLA operator review system performance and identify problem areas, and it provides data in the event that permit modifications are needed.

The WWLA operator should review the reuse permit to determine recordkeeping requirements. Typically, these include the following:

- Daily irrigation volumes, by hydraulic management unit for recycled water and supplemental irrigation water
- Flow measurements
- Effluent sampling data
- Ground water monitoring well sampling data
- Soil monitoring data
- Crop maintenance activities, including crop yield and plant tissue monitoring
- Lagoon freeboard measurements

Additionally, a record or logbook of daily activities can assist WWLA operators with tracking both permit required and recommended activities. Examples may include the following:

- Equipment maintenance procedures
- Equipment maintenance problems and corrective action
- Equipment replacement
- Site visits from inspectors or technical assistance professionals
- Complaints and how they were addressed
- Dates and locations of soil samples taken
- Dates and locations of vegetation samples taken
- Crop problems and resolution
- Irrigation system modifications or malfunctions
- Supplemental fertilizer applications (type and quantity)
- Abnormal operations such as diversions of recycled water, unplanned shutdown of major equipment, and wastewater treatment upsets

13.6 Environmental Protection

Recycled water application activities must be planned and managed to prevent adverse impacts to ground water, surface water, and public health. Adverse environmental impacts of land application can be minimized by proper management of the following:

- Hydraulic- and constituent-loading rates
- Timing of irrigation
- Buffer zones
- Recycled water constituents
- Irrigation system performance

Adverse effects to the environment are minimized by maintaining buffer zones, controlling the quantity and quality of water applied, and maintaining a healthy soil-crop system for final treatment. In addition, a land application site should be restricted to authorized personnel to prevent mishaps involving the public and to ensure that the site and all equipment are protected from vandalism and theft.

13.6.1 Emergency Action Plans for Spills and Releases

The WWLA operator is required to report all noncompliance incidents to the applicable DEQ regional office according to the standard permit conditions. As part of the permitting process, an emergency action plan is required for most land application sites. A land application facility should have an emergency action plan to have a predetermined plan of action for quick response in the event that wastewater, recycled water, other waste materials, or chemicals from site operations, leak, overflow, or run off the site.

Note
The WWLA operator should NOT wait until wastewater, recycled water, waste materials, or chemicals reach surface waters or leave the land application site to determine that a problem exists. Every effort should be made to ensure that this does not happen. The emergency action plan should be available to all employees at the facility, since accidents, leaks, and breaks can happen at any time.

The emergency action plan should follow four steps:

1. Stop the release of the waste material.
2. Assess the extent of the spill and note any obvious damages.
3. Contact the appropriate agencies.
4. Implement procedures to rectify the damage and repair the system.

13.6.1.1 Step 1: Stop the Release of the Waste Material

Spills must be contained immediately and the material should be pumped back to a storage facility or contained if possible. Facilities should have the necessary equipment and supplies to respond to a chemical or wastewater spill. Suggested responses to several problems are listed below:

Storage lagoon overflow (see Note)

1. Add soil or sandbags to berm to increase elevation of dam.
2. Pump recycled water to fields at an acceptable rate.
3. Stop all additional flow to the structure.
4. Call a pumping contractor if additional pumping or equipment is needed.
5. Ensure no surface water is entering storage structure.

Note
These activities should be started when your storage facility level has exceeded the maximum design storage level, not including the freeboard.

Runoff from land application field

1. Immediately stop the application.
2. Create a temporary diversion or berm to contain the water on the field.
3. Pump the contained water back to a storage structure.
4. Incorporate water into soil to reduce further runoff.
5. Evaluate and eliminate the reason that caused the runoff.
6. Evaluate the application rates for the fields where runoff occurred.

Leakage from the recycled water distribution system (pipes and sprinklers)

1. Stop irrigation pump.
2. Close valves to eliminate further discharge.
3. Separate pipes to create an air gap and stop flow.
4. Repair all leaks prior to restarting pumps.

Leakage from base or sidewall of lagoons or earthen storage structures (includes seepage as well as flowing leaks) Evaluate the situation first, for catastrophic failure and drain structure if necessary. Otherwise consider the following:

1. Dig a small well or ditch to catch all seepage, put in a submersible pump, and pump back into storage area.
2. If holes are caused by burrowing animals, trap or remove animals and fill holes and compact with a clay-type soil.
3. Temporarily plug other holes with clay soil.

Note
Problems with lagoons and earthen storage structures require the consultation of an individual experienced in the design and installation of lagoons for permanent repair measures.

13.6.1.2 Step 2: Assess Spill Extent and Damages

Assess the extent of the spill and determine damages by answering the following questions:

1. Did the wastewater or recycled water reach any surface waters?
2. Approximately how much was released and for what duration?
3. Any damage noted, such as employee injury, fish kills, or property damage?
4. Did the spill leave the property?
5. Does the spill have the potential to reach surface waters?

6. Could a future rain event cause the spill to reach surface waters?
7. Are potable water wells in danger (either on or off the property)?

13.6.1.3 Step 3: Contact Appropriate Agencies

1. To report a spill or accident involving oil, gas, or hazardous materials (e.g., chlorine or other chemicals used on site), immediately contact the Idaho State Communication Center (StateComm) at (800) 632-8000 or (208) 846-7610 and the nearest DEQ regional office. StateComm will activate Idaho's Emergency Response Network, which consists of state and local agencies (including DEQ field personnel) and, if necessary, federal agencies.
2. To report recycled water spills that would result in permit noncompliance, such as lagoon overtopping or runoff to nearby property, call the nearest DEQ regional office and follow the reporting requirements in section 6.2 of the facility reuse permit. Be prepared to provide the following:
   - Your name
   - Facility name
   - Telephone number
   - Details of the incident (Step 2)
   - Exact location of the facility
   - Location or direction of movement of the spill
   - Weather and wind conditions
   - Corrective measures taken
   - Assessment of the seriousness of the situation
3. If the spill results in an unpermitted discharge to surface waters of the United States, contact EPA at (208) 378-5746/(208) 378-5744 and EPA Hotline at (206) 553-1846 and follow the reporting requirements in section 6.2 of the facility reuse permit.

   Contact with DEQ and EPA must be made orally within 24 hours and in writing within 5 days.

   Based on the nature and quantity of the spill, additional contact to agencies may be required (e.g., local fire and police), but this is beyond the scope of this manual.

13.6.1.4 Step 4: Implement Procedures

As advised by the appropriate agencies and system design engineer, repair the system and reassess the facility to keep spills from happening again.

The emergency action plan must include provisions for emergency land application or transfer of wastewater from all wastewater storage structures in the system. The provision may include emergency pumping (to prevent overtopping of a storage structure) during periods when the soil or crop conditions are not conducive to normal application.

Note
DEQ must be contacted for guidance to land-apply wastewater in emergency situations.

The WWLA operator should consider which fields are best able to handle the wastewater or recycled water without further environmental damage. Application rates, methods, and minimum buffer distances must all be addressed.

The emergency action plan should be available and understood by all employees at the facility:

- The main points of the plan along with the relevant telephone numbers should be posted by all telephones at the site.
- A copy should also be available in remote locations or in vehicles if the land application sites are not close to the facility office.
- It is the responsibility of the permittee or system manager to ensure that all employees understand what circumstances constitute an imminent danger to the environment or to the health and safety of workers and neighbors.
- Employees should be able to respond to such emergencies and notify the appropriate agencies of conditions at the facility.

14 Calculations for Annual Reports and Permit Condition Compliance

Need-to-Know Criteria
Conversions
Concentration and constituent-loading rate calculations
Hydraulic-loading rate calculations
Plant-available nitrogen calculations
Run time for stationary sprinklers
Crop yield and crop uptake calculations

Calculations are needed to develop annual reports and determine permit condition compliance. A number of calculations are used in the operation and management of a land application system. Some calculations are made only once and recorded for future reference while others may be performed on a daily basis. In either case, WWLA operators should be familiar with the units of measurement, formulas, and calculations presented in this section.

To facilitate calculations in this section, the following conversion factors may be referenced:

- 1 acre inch (ac-in.) = 27,154 gallons
- 1 million gallon (MG) = 3.069 (acre feet)
- 1 MG = 36.827 ac-in.
- 1 inch = 25.4 millimeters

14.1 Units of Measurement

The appropriate units must be written with each number used in all land application system calculations. The units can then be multiplied and divided as though they were numbers, and it allows the correct units to be included in the results. Carrying units properly through a calculation serves as a check on the calculation and identifies units that need converting.

Inaccurate measurements and calculations can result in erroneous reports and costly operational decisions. Accurate measurements and calculations are important tools for properly controlling and managing land application processes.

In the following examples, note that all numbers have units (e.g., square feet, inches, and gallons). In several cases, conversion factors have been supplied to simplify the calculations; units are shown for these as well.

14.2 Types of Calculations

The WWLA operator must be familiar with a variety of calculations. In addition to calculations relevant to water flow, calculations are relevant to the managing soils, crops, fertilizers, constituent loadings, and irrigation equipment.

The following categories of calculations are presented in this section:

- Concentration of wastewater/recycled water constituents
- Constituent-loading rates
- Flow and hydraulic-loading rates
- Plant-available nitrogen calculations
- SAR calculations
- Hydraulic application rates
- Crop yield and crop uptake calculations

14.2.1 Concentration and Constituent-Loading Rate Calculations

Concentration is the measurement of the strength of a known constituent or substance (solid, liquid, or gas) dissolved in another substance. Concentration of a substance is usually expressed as a percent, as pounds per gallon (lb/gal), as milligrams per liter (mg/L or parts per million [ppm]), or as micrograms per liter (µg/L or parts per billion). Concentrations may be expressed in any of these units and may be changed between units if proper conversion factors are used. One of the most frequently used calculations is the conversion of milligrams per liter (mg/L) concentration to pounds (lb) of constituent loading.

The formulas presented by Equation 14-1 and Equation 14-2 are useful in converting between concentrations and constituent-loading rates:

To Convert mg/L to lb/day

$$\text{Pounds/day} = \text{concentration (mg/L)} * \text{Flow (MG/day)} * 8.34\ (\text{lb-L/MG-mg})$$

or

$$\text{lbs/day} = \text{mg/L} * \text{MGD} * 8.34\ \text{lb-L/MG-mg}$$

Equation 14-1. Converting mg/L to lb/day.

To Convert lb/day to mg/L

$$\text{Concentration (mg/L)} = \frac{\text{Pounds/day}}{\text{flow (million gallons per day)} * 8.34\ \text{lb-L/MG-mg}}$$

or

$$\text{mg/L} = \frac{\text{lbs/day}}{\text{MGD} * 8.34\ \text{lb-L/MG-mg}}$$

Equation 14-2. Converting lb/day to mg/L.

Example 1: Calculate Concentration, Constituent-Loading Rates

The recycled water applied at a land application site averages the following:

- 0.2 mg/L of nitrate + nitrite
- 12.3 mg/L TKN

- 5.2 mg/L ammonia
- 3.7 mg/L total phosphate
- 261 mg/L COD

The 120-acre land application site only operates during the growing season for 184 days out of the year. If the average daily hydraulic-loading rate is 0.1 million gallons per day (MGD or MG/day), determine the following:

1. Total nitrogen-loading rate in pounds per acre per year
2. Phosphorus-loading rate in pounds per acre per year
3. Growing season COD loading rate in pounds per acre per day

Solution

1. Nitrogen

Total Nitrogen	= (Nitrate + Nitrite) + TKN
	= 0.2 mg/L + 12.3 mg/L
	= 12.5 mg/L

Note
Recall from section 5.3.4.1 that TKN is the sum of organic nitrogen and ammonia.

lb/day	= (mg/L)(MGD)(8.34)
	= (12.5 mg/L)(0.1 MGD)(8.34 lb-L/MG-mg)
	= 10.4 lb/day
lb/year	= (10.4 lb/day)(184 days/year)
	= 1,918 lb/year N
lb/acre/year	= (1,918 lb/year N)/(120 acres)
	= 16.0 lb/acre/year N

2. Phosphorus

lb/day	= (mg/L)(MGD)(8.34)
	= (3.7 mg/L)(0.1 MGD)(8.34)
	= 3.09 lb/day
lb/year	= (3.09 lb/day)(184 days/year)
	= 568 lb/year P
lb/acre/year	= (569 lb/year P)/(120 acres)
	= 4.7 lb/acre/year phosphorus

3. COD

lb/day = (mg/L)(MGD)(8.34)

= (261 mg/L)(0.1 MGD)(8.34)

= 218 lb/day

lb/acre/day = (218 lb/day COD)/(120 acres)

= 1.8 lb/acre/day COD

14.2.2 Hydraulic-Loading Rate Calculations

Hydraulic-loading rate may be measured in inches applied to an area in a day (inches per day). To calculate the hydraulic-loading rate in inches per day (with flow to the land application field measured in gallons), use the following conversion factor: 1 inch of water times 1 acre (1 ac-in.) = 27,154 gallons (Equation 14-3, Figure 14-1).

$$\text{Hydraulic Loading Rate (in/day)} = \frac{\text{Flow (gallons per day)}}{27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * \text{Area (acres)}}$$

Equation 14-3. Calculation of hydraulic-loading rate (in./day).

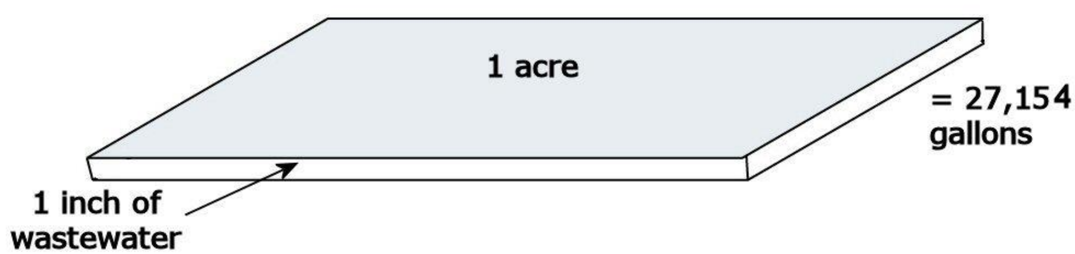

Figure 14-1. Acre with 1 inch of water = 27,154 gallons.

Hourly hydraulic-loading rate is inches of water applied to an area of soil in 1 hour. To calculate the hourly hydraulic-loading rate, use the hydraulic-loading rate formula and convert from inches per day to inches per hour as follows (Equation 14-4):

$$\text{Hydraulic Loading Rate (in/hour)} = \frac{\text{Hydraulic Load Rate (in)}}{1\,\text{day}} * \frac{1\,\text{day}}{24\,\text{hours}}$$

Equation 14-4.Calculation of hydraulic-loading rate (in./hour).

Example 1: Calculate Hydraulic-Loading Rate

What is the hydraulic-loading rate for a land application system that pumps 50,000 gallons in 1 day, equally, over a 4.28 acre site?

Using Equation 14-3,

$$\text{Hydraulic Loading Rate (in/day)} = \frac{50{,}000 \text{ (gallons per day)}}{27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * 4.28 \text{ acres}}$$

$$= \frac{50{,}000 \text{ (gallons per day)}}{116{,}219 \frac{\text{gallons}}{\text{inch}}}$$

$$= \frac{0.43 \text{ inches}}{\text{day}}$$

Example 2: Calculate Hydraulic-Loading Rate

What is the hydraulic-loading rate in inches per hour for a land application system that pumps 175,000 gallons in 1 day, equally, over a 10.5 acre site?

Using Equation 14-3 and Equation 14-4,

$$= \frac{175{,}000 \text{ (gallons per day)}}{27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * 10.5 \text{ acres}}$$

$$= \frac{175{,}000 \text{ (gallons per day)}}{285{,}117 \frac{\text{gallons}}{\text{inch}}} * \frac{1 \text{ day}}{24 \text{ hours}}$$

$$= \frac{0.02 \text{ inches}}{\text{hour}}$$

Example 3: Calculate Acres Given Hydraulic-Loading Rate and Flow

How many acres would be needed to achieve a hydraulic-loading rate of 0.35 in./day if the flow is 150,000 gallons per day (Figure 14-2)?

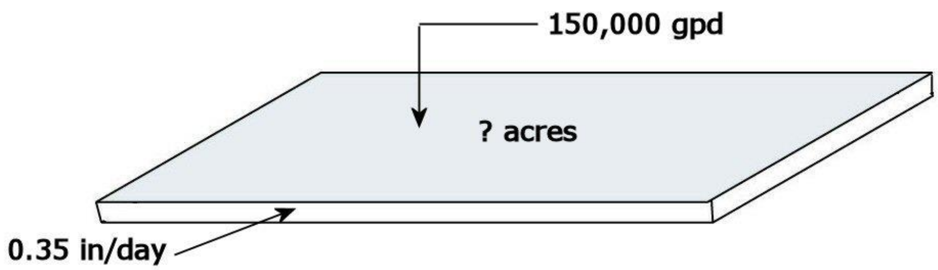

Figure 14-2. Pictorial representation for hydraulic-loading example 3.

Starting with Equation 14-3 and rearranging to solve for Area (acres), results in Equation 14-5.

$$\text{Area (acres)} = \frac{\text{Flow (gallons per day)}}{27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * \text{Hydraulic Loading Rate (in/day)}}$$

Equation 14-5. Calculation of area (acres) using hydraulic-loading rate.

Using equation 14-5 yields the following:

$$\text{Area (acres)} = \frac{150{,}000 \text{ (gallons per day)}}{27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * 0.35 \frac{\text{in}}{\text{day}}}$$

$$= \frac{150{,}000 \text{ (gallons per day)}}{9{,}503.9 \text{ gpd/acre}}$$

$$= 15.8 \text{ acres}$$

Example 4: Calculate Flow Given Acreage and Hydraulic-Loading Rate

If a land application field is 15.5 acres and receives 0.50 in./day of recycled water, what is the flow in gallons per day (Figure 14-3)?

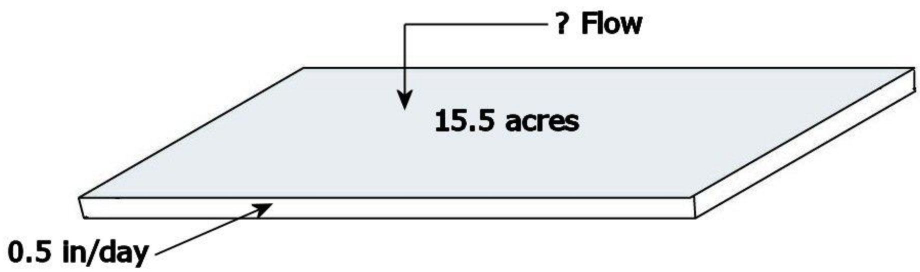

Figure 14-3. Pictorial representation for hydraulic-loading example 4.

Starting with Equation 14-3 and rearranging to solve for Flow (gallons per day), results in Equation 14-6.

$$\text{Flow (gallons per day)} = \text{Hydraulic Loading Rate (in/day)} * 27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * \text{Area (acres)}$$

Equation 14-6. Calculation of flow (gallons per day) using acres and hydraulic-loading rate.

Using Equation 14-6 yields the following:

$$\text{Flow (gallons per day)} = 0.5 \text{ in/day} * 27{,}154 \frac{\text{gallons}}{\text{acre - inch}} * 15.5 \text{ acres}$$

Flow (gallons per day) = 210,444 gpd

As described in section 5.4.1, the permitted irrigation amount (hydraulic-loading rate) for the growing season is substantially equal to the *irrigation water requirement* (IWR). IWR is defined as any combination of wastewater and supplemental irrigation water applied at rates commensurate to the moisture requirements of the crop, and calculated monthly during the *growing season*.

Calculation methodology for the IWR is found at the following website: *http://data.kimberly.uidaho.edu/ETIdaho/.*

Equation 14-7 is used to calculate the IWR at this website:

$$IWR = (CU - Pe) / Ei = IR / Ei = P_{def} / E_i$$

Equation 14-7. Calculation of irrigation water requirement.

where:

CU is the monthly consumptive use for a given crop in a given climatic area. CU is synonymous with crop evapotranspiration.

Pe is the effective precipitation.

CU minus Pe is synonymous with the *net irrigation requirement* (IR)

P_{def} is synonymous with the net irrigation requirement

E_i is the irrigation system efficiency. To obtain IWR, divide the P_{def} by E_i .

For permit purposes, the soil carry over moisture and leaching rates are assumed to be zero, and therefore, are not considered when calculating the IWR.

Example 5: Calculate Growing Season Irrigation Water Requirement

Determine the growing season IWR in million gallons given the following:

- Location of land application site: Coeur d'Alene
- Crop: alfalfa
- Irrigation equipment efficiency: 80% (0.80)
- Land application acreage: 120 acres

1. Determine the P_{def} by consulting the following website (Coeur d'Alene, alfalfa hay crop): *http://data.kimberly.uidaho.edu/ETIdaho/.*
2. The P_{def} for the growing season is given as 625 millimeters (mm):
   IWR = (625 mm)/(25.4 mm/in.)/(0.80)
   = 30.8 inches
3. Convert to million gallons:
   IWR = (30.8 in.)(27,154 gal/ac-in.)(120 ac)
   = 100,223,917 gallons = 100.2 MG

As described in section 5.4.1, the *nongrowing season* (NGS) hydraulic-loading rate is generally limited to the value given by Equation 14-8.

$$\text{Maximum (NGS) Hydraulic Loading Rate} = \text{Available Water-Holding Capacity of the Soil} + \text{Evapotranspiration in the NGS} - \text{Expected Precipitation in the NGS}$$

Equation 14-8. Calculation of nongrowing season hydraulic-loading rate.

This loading rate assumes a leaching rate of zero.

Example 6: Calculate Nongrowing Season Hydraulic-Loading Rate

Determine the nongrowing season hydraulic-loading rate in million gallons, given the following:

- Land application acreage: 120 acres
- Soil type: Quincy
- Effective root depth: 60 inches
- Precipitation in NGS, from DEQ guidance: 5.78 inches
- Evapotranspiration in NGS, from Agrimet: 4.82 inches

1. Determine the available water-holding capacity (AWC) of the soil. Refer to the soil survey report; the AWC data for the Quincy soil type is as follows:
   - 0–9 inches, AWC = 0.095 in./in.
   - 9–60 inches, AWC = 0.10 in./in.

   Therefore, AWC = 9 in. x 0.095 in./in. + 51 in. x 0.10 in./in. = 5.96 inches.

2. Calculate NGS hydraulic-loading rate:
   NGS HLR = AWC + ET – Precipitation
   = 5.96 in. + 4.82 in. – 5.78 in.
   = 5.00 inches

3. Convert to million gallons:
   NGS HLR = (5.00 in.)(27,154 gal/ac-in.)(120 ac)
   = 16,292,400 gallons = 16.3 MG

14.2.3 Plant-Available Nitrogen Calculations

Some land application systems handle water with high nitrogen concentrations. These systems should evaluate application rates based on supplying crop nitrogen needs rather than on the amount of water the soil-crop system can handle. PAN is calculated as shown in Equation 14-9.

$$PAN = [MR \times (TKN - NH_3)] + [(1\text{-}VR) \times (NH_3)] + [NO_3 + NO_2]$$

Equation 14-9. Calculation of plant-available nitrogen.

where:

PAN = Plant-available nitrogen

MR = Mineralization rate

VR = Volatilization rate

TKN = Total Kjeldahl nitrogen

NH_3 = Ammonia nitrogen concentration

NO_3 = Nitrate nitrogen concentration

NO_2 = Nitrite nitrogen concentration

VR = 0.50 for all treatment types

MR = 0.4 for primary treatment
0.3 for aerated lagoons and sand filters
0.2 for aerobic treatment/activated sludge systems

This PAN formula simplifies to Equation 14-10.

$$PAN = [MR \times (TKN - NH_3)] + [0.5 \times (NH_3)] + [NO_3 + NO_2]$$

Equation 14-10. Simplified calculation of plant-available nitrogen.

Example 1: Plant-Available Nitrogen

Apply 15 in./acre/year to the land application field. The irrigation water contains the following concentrations:

- TKN: 56 mg/L
- Ammonia: 18 mg/L
- Nitrate: 10.5 mg/L
- Nitrite: 0.5 mg/L

Assuming a mineralization rate of 0.40, how much PAN are you applying per year to each acre?

$$PAN = [MR(TKN - NH_3)] + [0.5(NH_3)] + (NO_3 + NO_2)$$

$$PAN = [(0.40)(56 - 18)] + [(0.5)(18)] + (10.5 + 0.5)$$

$$PAN = (0.40)(38) + 9 + 11$$

$$PAN = 15.2 + 9 + 11 = 35.2 \text{ mg/L PAN}$$

Convert milligrams per liter to pounds using Equation 14-1 as follows:

$$\text{lbs/day} = \text{mg/L} * \text{MGD} * 8.34 \text{ lb - L/MG - mg}$$

First, convert the hydraulic-loading rate from inches to million gallons.

$$\text{Flow} = (15 \text{ in./acre})(27{,}154 \text{ gal/ac-in.})(1 \text{ acre})$$
$$= 407{,}310 \text{ gal/acre}$$
$$= 0.407 \text{ MG/acre}$$

Then, solve for pounds PAN per year on each acre:

$$\text{Lb PAN/acre} = (35.2 \text{ mg/L PAN})(0.407 \text{ MG/acre/year})(8.34 \text{ lb - L/MG - mg})$$
$$= 119.5 \text{ lb/acre/year PAN}$$

14.2.4 Sodium Adsorption Ratio Calculations

The ratio of the sodium concentration to the concentrations of calcium and magnesium in recycled water is the *sodium adsorption ratio* (SAR). Calculations for SAR use the liquid concentrations (milligrams per liter) of sodium, calcium, and magnesium in the water. The formula for SAR is given by Equation 14-11, with all concentrations expressed in *milliequivalents* (meq) (Equation 14-12). If concentrations in Equation 14-11 are not expressed in *milliequivalents*, the equation will not yield the correct results:

$$SAR = \frac{Na}{\sqrt{0.5(Ca + Mg)}}$$

Equation 14-11. Calculation of sodium adsorption ratio.

$$meq = \frac{\text{concentration (mg/L)}}{\textit{equivalent weight}}$$

Equation 14-12. Calculation of milliequivalents.

where:

SAR = Sodium adsorption ratio
Na = Sodium concentration (meq)
Ca = Calcium concentration (meq)
Mg = Magnesium concentration (meq)

Example 1: Sodium Adsorption Ratio

What is the SAR for a wastewater that has the following ion concentrations:

- Sodium (Na^{+}) = 84 mg/L
- Calcium (Ca^{2+}) = 23 mg/L
- Magnesium (Mg^{2+}) = 14 mg/L

The equivalent weights of sodium, calcium, and magnesium are, respectively, 23, 20, and 12. (Note: for sodium, calcium, and magnesium, equivalent weight = molecular weight / ion charge.)

First, convert concentrations to milliequivalents (meq).

$$Na^{+} = \frac{84 \text{ mg/L}}{23} = 3.7$$

$$Ca^{2+} = \frac{23 \text{ mg/L}}{20} = 1.2 \qquad SAR = \frac{Na}{\sqrt{0.5(Ca + Mg)}}$$

$$Mg^{2+} = \frac{14 \text{ mg/L}}{12} = 1.2$$

Then, solve for SAR

$$SAR = \frac{3.7}{\sqrt{0.5(1.2 + 1.2)}} = \frac{3.7}{\sqrt{0.5(2.4)}} = \frac{3.7}{\sqrt{1.2}} = \frac{3.7}{1.1} = 3.4$$

14.2.5 Reuse Water Application Rate and Run Time Calculations

The formulas presented by Equation 14-13 and Equation 14-14 are useful in calculating the irrigation rate and run time for stationary sprinklers:

$$\text{Irrigation rate (in./hr)} = \frac{96.3 \text{ x discharge rate (gpm)}}{\text{sprinkler spacing (ft) x lateral spacing (ft)}}$$

Equation 14-13. Calculation of reuse water application rate.

$$\text{Run time (hours)} = \frac{\text{target application depth (inches)}}{\text{irrigation rate (in./hr)}}$$

Equation 14-14. Calculation of sprinkler run time.

Example 1: Irrigation Rate for Stationary Sprinklers

A stationary sprinkler has a discharge rate of 17.6 gpm and a wetted diameter of 140 feet. If the sprinkler spacing is set at 60% of the wetted diameter and lateral spacing is 84 feet, what is the irrigation rate in inches per hour?

First, determine the design sprinkler spacing:

Sprinkler spacing = 140 feet x 0.6 = 84 feet

Next, determine the irrigation rate using Equation 14-13:

$$\text{Irrigation rate (in./hr)} = \frac{96.3 \text{ x discharge rate (gpm)}}{\text{sprinkler spacing (ft) x lateral spacing (ft)}}$$

$$= \frac{96.3 \text{ x } 17.6 \text{ gpm}}{84 \text{ x } 84 \text{ feet}} = 0.24 \text{ in./hr}$$

Example 2: Irrigation Rate for Stationary Sprinklers

A stationary sprinkler has a discharge rate of 13.0 gpm and a wetted diameter of 127 feet. If the sprinkler spacing is set 70 feet and the lateral spacing is set at 80 feet, what is the irrigation rate in inches per hour?

$$\text{Irrigation rate (in./hr)} = \frac{96.3 \text{ x discharge rate (gpm)}}{\text{sprinkler spacing (feet) x lateral spacing (feet)}}$$

$$= \frac{96.3 \text{ x } 13.0 \text{ gpm}}{70 \text{ x } 80 \text{ feet}} = 0.22 \text{ in./hr}$$

Example 3: Run Time for Stationary Sprinklers

If a stationary sprinkler has an irrigation rate of 0.26 in./hr and your target application depth is 0.25 inches, what is the run time for the sprinkler? Using Equation 14-14 yields the following:

$$\text{Run time (hours)} = \frac{\text{target application depth (inches)}}{\text{irrigation rate (in./hr)}}$$

$$= \frac{0.25 \text{ in.}}{0.26 \text{ in./hr}} = 1 \text{ hour}$$

Example 4: Run Time for Stationary Sprinklers

If stationary sprinkler has an irrigation rate of 0.22 in./hr and your target application depth is 0.75 inches, what is the run time for the sprinkler?

$$\text{Run time (hours)} = \frac{\text{target application depth (inches)}}{\text{irrigation rate (in./hr)}}$$

$$= \frac{0.75 \text{ in.}}{0.22 \text{ in./hr}} = 3.4 \text{ hours}$$

14.2.6 Crop Yield and Crop Uptake Calculations

Many reuse permits specify the maximum nitrogen (and sometimes phosphorus) loading rates as 125% or 150% of typical crop uptake values. *Typical crop uptake* is defined as the median constituent crop uptake from the 3 most recent years the crop has been grown. Typical crop uptake is determined for each hydraulic management unit (typically a single field at a land application site). For new crops having less than 3 years of on-site crop uptake data, regional crop yield data and typical nutrient content values, or other values approved by DEQ may be used.

Example 1: Crop Yield and Crop Uptake

Determine the maximum nitrogen-loading rate in pounds per acre per year given the following:

- Permitted nitrogen-loading rate is 150% of crop uptake
- Two cuttings of alfalfa this year
  - Cutting 1: Dry yield of 2.8 ton/acre
  - Cutting 2: Dry yield of 3.7 ton/acre
- Plant tissue analysis results, dry protein percentage
  - Cutting 1: Dry protein percentage of 11.7%
  - Cutting 2: Dry protein percentage of 12.9%
- Conversion factors for % protein to % TKN
  - Small grain: 5.72
  - Other plant tissue (including alfalfa): 6.25

- Plant tissue analysis results, dry nitrate-N concentration
  - Cutting 1: Dry nitrate-N concentration of 2,860 ppm
  - Cutting 2: Dry nitrate-N concentration of 2,150 ppm

Note
Crop yield and nitrogen percentage data must be on the same moisture basis.

1. Convert % protein to % TKN:
   Cutting 1: 11.7% protein / 6.25 = 1.87% TKN
   Cutting 2: 12.9% protein / 6.25 = 2.06% TKN
2. Convert nitrate-N concentration from parts per million (ppm) to %:
   Cutting 1: (2,860 ppm/1,000,000) * 100% = 0.286 % nitrate-N
   Cutting 2: (2,150 ppm/1,000,000) * 100% = 0.215 % nitrate-N
3. Calculate total % nitrogen:
   Cutting 1: 1.87 % + 0.286 % = 2.156% total nitrogen = 0.02156 total nitrogen
   Cutting 2: 2.06 % + 0.215 % = 2.275% total nitrogen = 0.02275 total nitrogen
4. Calculate crop nitrogen uptake:
   Cutting 1: (2.8 ton/ac) x (2,000 lb/ton) x (0.02156) = 121 lb N/ac

   Cutting 2: (3.7 ton/ac) x (2,000 lb/ton) x (0.02275) = 168 lb N/ac
5. Calculate total crop nitrogen uptake:
   121 lb N/ac + 168 lb N/ac = 289 lb/ac/yr
6. Calculate maximum nitrogen-loading rate:
   1.50 x 289 lb/ac/yr = 434 lb/ac/yr total nitrogen

Example 2: Moisture Content used for Crop Uptake

To determine the ash crop uptake, the harvested moisture content of the crop is required.

Equation 14-15 is used to determine moisture content:

$$\text{Moisture Content (\%)} = \left(\frac{\text{Weight of the Water (tons)}}{\text{Crop Yield (tons)}}\right) * 100\%$$

Equation 14-15. Calculation of crop moisture content.

With alfalfa and other crops, harvested moisture content can be referred to as fresh or green cut (wet moisture content) or after it is field dried (dry moisture content). So read the question carefully to determine what is being asked for.

Determine the dry moisture content given the following:

- Dry weight = 4 tons
- Weight of water in dry alfalfa = 0.25 tons

Using Equation 14-15 yields the following:

$$\text{Dry Moisture Content (\%)} = \left(\frac{0.25\ \text{tons}}{4\ \text{tons}}\right) * 100\%$$

= 6.25 %

Example 3: Crop Yield

Determine the dry weight of the alfalfa hay given the following:

- Harvest weight = 5 tons
- Harvest moisture content (wet) = 30%
- Dry moisture content = 9%
  Weight of water in dry alfalfa = 0.25 tons

Starting with Equation 14-15 and rearranging, results in Equation 14-16.

$$\text{Crop Yield (tons)} = \left(\frac{\text{Weight of the Water (tons)}}{\text{Moisture Content (\%)} / 100\%}\right)$$

Equation 14-16. Calculation of crop yield.

Crop yield or $\text{Dry weight (tons)} = \frac{0.25\ \text{tons}}{(9\% / 100\%)}$

= 2.78 tons

15 Health and Safety

Need-to-Know Criteria
Personal protective equipment
Health and safety hazards and measures
Lockout and tagout policy
Public health and safety

Accidents and injuries do not just happen; they are caused. Behind every accident is a chain of events that leads up to an unsafe act, unsafe conditions, or a combination of both.

Communication between supervisors and employees generates ideas and safety awareness that leads to accident prevention. Safety programs, manuals, and meetings are essential in providing the lines of communication that lead to a safe, accident-free workplace. Some of the minimum recommended safety tips are discussed below. Additional site-specific safety requirements should be covered in the facility PO.

15.1 Regulatory Overview

A variety of federal and state laws and regulations exist to protect workers in both the private and public sectors. At the federal level, the regulatory agency that oversees worker safety is the United States Occupational Safety and Health Administration (OSHA). OSHA oversight does not include state or local government employees. In Idaho, state and local government public employee safety and health are overseen by the Idaho Division of Building Safety. These safety standards are designed, at a minimum, to meet or exceed the OSHA standards.

15.1.1 Employer Responsibilities

The permittee is responsible for the following:

- Provide a workplace that is free from recognized hazards that are causing or likely to cause serious injury or death.
- Furnish and require use of safety devices and safeguards, safe work practices and procedures, and operations and processes that are adequate to ensure employees are safe while performing their jobs.
- Comply with all OSHA and/or state standards.

15.1.2 Site Supervisor Responsibilities

The site supervisor is responsible for the following:

- Establish and supervise a Health and Safety Program that is designed to improve the safety and health skills and competency of all employees.
- Conduct preliminary investigations to determine the cause of any accident that results in injury. The results of this investigation should be documented for reference.

- Establish and maintain a system for maintaining records of occupational injuries and illnesses.
- Provide new employees with a safety orientation on the special hazards and precautions of any new job.
- Conduct job briefings with employees before starting any job, to acquaint employees with any unfamiliar procedures.
- Issue any needed safety equipment and manuals.
- Conduct periodic group safety meetings.

15.1.3 Employee Responsibilities

Employees have the responsibility to do the following:

- Comply with OSHA and/or state standards and rules that are applicable to their own actions and conduct.
- Keep informed of current safe work practices and procedures.
- Be responsible for their own safety.
- Request instruction from the site supervisor if there is a question as to the safe performance of work assigned.
- Use appropriate safety devices and wear suitable clothing and appropriate personal protective equipment (PPE).
- Report *any* unsafe conditions, practices, or procedures to the site supervisor

15.2 Health and Safety Program

As mentioned above, the site supervisor is responsible for developing a Health and Safety Program. This program should include the following:

- Procedures for reporting incidents, injuries, and unsafe conditions or practices
- Instructions on identification and safe use of hazardous gases, chemicals and materials, and emergency procedures following exposure
- Use and care of PPE

15.2.1 Incident Reporting

As part of the Health and Safety Program, all facilities should develop a formal incident reporting and investigation program. All incidents, including injuries, accidents, and near misses should be reported to the site supervisor immediately, and these incidents should be investigated as soon as possible to determine their root causes.

The information gained from an investigation should then be used to change work practices and to eliminate hazardous activities. Injuries requiring treatment other than first aid treatment must be reported on OSHA 200 form (Log and Summary of Injuries and Illnesses).

15.2.2 Hazard Communication Standard

The “Hazard Communication” standard (29 CFR 1910.1200), mandated by OSHA, is another important component of any Health and Safety Plan. The goal of 29 CFR 1910.1200 is to reduce injuries and illnesses resulting from improper use and storage of chemicals in the workplace. Employers must inform or instruct employees about the following when chemicals that are used in the workplace:

- Safety and health standards for the safe use of chemicals
- Known health hazards of the chemicals used in the workplace
- Methods of hazard control
- Proper labeling of containers
- Maintaining current *material safety data sheets* on all chemicals
- Chemical inventory
- Emergency procedures versus nonemergency procedures
- Training in recognizing, evaluating, and controlling hazards

15.2.3 Chemical Hygiene Plan

OSHA's laboratory standard requirements are found in the "Occupational Exposure to Hazardous Chemicals in Laboratories" (29 CFR 1910.1450). Facilities with a laboratory that performs analytical tests may need to develop a *chemical hygiene plan*. A chemical hygiene plan includes instruction on the following topics:

- How laboratory personnel handle and work with hazardous laboratory chemicals
- How employee exposure to these chemicals will be minimized
- What PPE will be used in the laboratory
- Specifications for working with particularly hazardous substances, such as cancer-causing chemicals, and other requirements.

The chemical hygiene plan must be a written plan and must be evaluated on a regular basis for effectiveness.

15.2.4 Personal Protective Equipment

Another important component of a Health and Safety Program is a written program covering the appropriate selection, use, and maintenance of PPE. The proper selection and use of PPE is one of the most effective methods for preventing occupational injuries and illnesses. Types of PPE include the following:

- Head protection
- Eye and face protection
- Hearing protection
- Foot and leg protection
- Body protection
- Respiratory protection

15.2.4.1 Head Protection

Any head injury has the potential to be serious. Any injury that results in brain damage can cause memory loss, affect the ability to reason, and cause changes in personality and emotions. Any of these changes can result in disability and interfere with the ability to earn a living. Fortunately, a variety of PPE is suitable for the activities normally associated with wastewater treatment facilities:

Bump caps are lightweight plastic caps designed to protect the head from bumps and scrapes encountered in tasks such as building and machinery maintenance. A bump cap will not provide protection from impact, such as a dropped tool or other heavy object, but bump caps are recommended for tasks where cleanliness and sanitation are high priorities, such as in food processing plants or when handling pesticides. A bump cap or hard hat can be decontaminated with soap and water, but a baseball cap or cowboy hat cannot be completely decontaminated of chemicals.

Safety helmets (hard hats) are primarily intended to protect the head from falling objects, although they can also provide protection from flying objects. A hard hat consists of a sturdy shell, usually made of plastic, and a suspension that holds the shell at least 1-1/4 inches from the head. When an object strikes the hat, the force is distributed through the suspension to a large area of the head and neck, preventing puncture wounds and concussion injuries in most cases. Hard hats are recommended for all construction and timber harvesting activities and any other tasks involving the risk of bumps or falling objects. While a hard hat may not be able to protect a person from a severe, direct blow, it can deflect many glancing blows that might otherwise result in serious injury or death.

Accessories that can be mounted on a hard hat include welding helmets, face shields, hearing protectors, and communications devices. These devices are useful because several PPE items needed for a particular task can be kept together. For example, a hard hat with a face screen and hearing protectors is ideal for chain saw operation.

Although hard hats are heavier than baseball caps, they are cooler than baseball caps because there is an air space between the head and shell. This coolness is welcomed in summer, but a liner is often needed in winter to maintain comfort.

Accidents, abuse, or improper care can damage any type of protective headgear. Remember these points:

- Always replace any protective headgear that has received a hard blow because it may have sustained damage that is not visible.
- Never wash any protective headgear with anything stronger than mild detergent and water. Solvents can weaken or destroy the plastics used for protective headgear.

Note
Use safety helmets that comply with the American National Standards Institute Z89.1 criteria. Never use a metal hard hat when working around electrical systems.

15.2.4.2 Eye and Face Protection

Our eyes are one of the most vulnerable parts of our bodies. Chemical burns, flying particles, cuts, heat, light, and blows to the head or face cause eye injuries. Eye and face protective devices include face shields, safety glasses, and goggles.

Safety glasses are available in a wide variety of styles and can be equipped with or without side shields. Lenses can be made of plastic or heat treated/chemically treated glass. Metal frames should not be worn in an electrical hazard area.

Goggles can be worn over regular prescription eyewear. Goggle frames are made of molded synthetic rubber, natural rubber or vinyl, and lenses are made of plastic, acetate, or glass. Goggles with ventilation should be used where fogging is a problem. In areas where dust, smoke, aerosols, chemical splashes, or fumes can irritate eyes, goggles without ventilation should be used.

Face shields provide additional protection for eyes and should only be worn over primary eye protection. The shields also provide protection for the nose, mouth, and throat. Face shields are generally made of plastic but are available in reflecting metal screen where radiant heat is a problem. Face shields can be attached directly to a hard hat.

15.2.4.3 Hearing Protection

Noise is a fact of life; however, noise above a certain level can be harmful and cause permanent hearing damage. Noise can come from a variety of sources, such as gasoline or diesel engines, gas or electric blowers, mechanical equipment, spreaders, and other types of machinery.

Each employer is required to determine if noise above what is called the *action level* exists in the workplace. If so, actions must be taken to reduce the noise level and protect the employees. The employer is required to develop a *hearing conservation program*, which is designed to effectively limit employee exposure to harmful levels of noise.

OSHA's standard on "Occupational Noise Exposure" (29 CFR 1910.95) stipulates what a minimum level hearing conservation program must contain and provides guidance for employers to develop their own effective program. The hearing conservation program states that employees must wear proper ear-protecting devices whenever they are working in a noise hazard area. Hearing protection devices include earplugs, earmuffs, and semiaurals or canal caps.

15.2.4.4 Hand and Arm Protection

One of the best methods of protecting the hands (and preventing dermatitis elsewhere) is to thoroughly wash the hands with soap and water and dry them with single-use towels when finishing a task, before eating, and after using the restroom.

Gloves also provide hand and arm protection, and they are available in a wide variety of styles and materials, each having its advantages and disadvantages. Since there is no single type of glove that is suitable for all tasks, it is important to understand a few basics of selecting gloves. When determining the types of gloves to use, ask the following questions:

- Do you need protection from cuts and scrapes, protection from heat, or protection from chemicals?
- Are the hazards low, moderate, or high?
- Do you need to wear gloves all day or intermittently?
- Do you need good manual dexterity for handling controls, tools, or small objects?

Glove selection becomes complicated when a situation involves several hazards or types of tasks.

Chemical labels are required to give specific recommendations for PPE, including gloves. The PPE stated on the chemical label must be used to comply with federal and state regulations. Check the label for PPE recommendations, or refer to a chemical resistance chart (featured in safety product catalogs), and select a material that provides good to excellent resistance from the chemicals you will be exposed to. Never use leather or fabric gloves when handling toxic chemicals—chemicals readily penetrate these materials, and they can never be fully decontaminated.

Gloves are made from many materials. Three to four types of gloves may be needed. The choices will depend on the specific needs for protection from chemical and physical hazards.

Fabric (e.g., jersey, cotton flannel, and knit) gloves are inexpensive and suitable for many tasks where protection is needed from minor cuts and scrapes. Cloth gloves are also ideal for tasks where protection is needed from friction or when a glove might aid in gripping objects. Gloves with dimples or rubberized fabric on the palms and fingers are excellent when using hand tools and other similar tasks.

Some fabrics are also used for high temperature applications, such as welding. Cloth gloves may be more flexible than leather welding gloves but can result in serious burns if they are wet when a hot object is picked up—unless they have a moisture barrier. A significant advantage of cloth gloves is that they breathe well, minimizing perspiration buildup.

Leather is possibly the best all-around choice for protection from cuts, scrapes, friction, and other physical hazards. Leather is tough, flexible, inexpensive, and it breathes well. Leather can be sewn into a wide variety of gloves, and it may be used in conjunction with other materials for specialized purposes. For example, Kevlar (the material used in body armor for police officers) is used in gloves for chain saw operators to provide extra protection from cuts should the left hand come in contact with the moving chain. Another example is the insulating materials sewn inside gloves used by welders to protect them from burns.

Rubber gloves are needed for protection from the wide variety of chemicals that may be used at a spray irrigation site. However, several *rubber* materials are used for gloves today, and it is important that the correct material be used. Using the wrong material can allow chemicals to penetrate through the gloves or cause the gloves to deteriorate. Always refer to the manufacturer's chemical resistance chart and glove selection guidelines when selecting rubber gloves.

Cut-resistant materials such as Kevlar, steel-reinforced fabrics, and chain link mesh are used in gloves designed for tasks where cuts are a major risk, such as handling glass and other sharp objects. Although these materials can be cut, they offer superior protection while permitting the user to grasp tools and other objects. Cut-resistant gloves often feature slip-resistant materials or textures on the fingers and palm to minimize the risk of sharp objects slipping through the hands, thus reducing the risks of a cut.

Whatever type of gloves are chosen, remember these points:

- Gloves should be thick enough to provide adequate chemical resistance and prevent punctures or tears, yet thin enough to provide a good grip and manual dexterity. Examination gloves (like doctors use) are not adequate for protection from most chemicals, especially pesticides.
- Unlined gloves are normally recommended when using chemicals since they can be easily washed and decontaminated. Flock-lined gloves are more comfortable, however, and often cost less than unlined gloves. Any lined gloves should be disposed of if contaminated inside by chemicals.
- The color of the gloves will affect comfort, especially outdoors. Black gloves will absorb heat from the sunlight, making them uncomfortable, so select a lighter color for outdoor work.
- Cut, length, and thickness affect the comfort and performance of any glove. Some gloves may be so heavily constructed that they will last forever, but are too stiff or otherwise uncomfortable to be used on a routine basis. Gloves that are too heavy or uncomfortable, or which do not fit well, can significantly reduce a worker's productivity by making it difficult to handle tools and other objects. Those gloves can also be dangerous in certain situations. Other gloves may be very comfortable, but not durable enough to provide satisfactory performance and economy. The ideal glove fits well, provides the needed protection, permits good productivity, and is economical. If there are several workers, it is likely that several styles or sizes of gloves will be needed. Try several styles of gloves to determine which provides the best comfort, grip, and dexterity needed for the intended tasks.

15.2.4.5 Foot and Leg Protection

Injuries to the feet are uncomfortable at best, and they can seriously interfere with the ability to accomplish work activities. Although most foot injuries are not serious, they do result in pain and lost production. Injuries resulting from dropped objects, punctures, and strains or sprains due to slips and falls are probably the most common. Most of these can be prevented through a combination of safe work practices and use of proper footwear. While high-top steel-toe boots with steel shank and lug soles are not always needed, you probably should wear them some of the time. Sneakers and smooth soled shoes are not good because they do not provide protection from commonly encountered hazards.

Perhaps the most important aspect of good footwear is a nonslip sole. Good traction is needed to prevent slips and falls while walking on various surfaces, and especially when climbing ladders and stairs. Smooth leather soles common on western boots and dress shoes may be too slippery on many surfaces. Soles with lugs or texture may provide better traction, especially when made of the soft, yet long wearing materials found in quality boots. A steel shank can provide improved puncture resistance as well as improved support in activities that place concentrated loads on the feet, such as prolonged work on ladders or repeatedly pressing machinery brake pedals.

Steel toe safety shoes protect the toes from injuries caused by dropped objects. While steel toecaps are very effective in preventing injuries to the toes, they will not protect the rest of the foot. Like any shoes or boots, safety shoes will not be comfortable unless they fit properly. Most reputable safety shoe dealers can fit all sizes and widths from AAAA to EEE. If they fit properly, the steel toe cap will only be noticed if it prevents an injury, when you are squatting, or otherwise have your toes bent far back, or if you kick something and push your toes against the toe cap.

Safety shoes are available in a wide variety of styles, including dress shoes and western boots, as well as leather and rubber work boot styles. Some special purpose boots are available that incorporate instep guards to prevent injuries behind the toes, Kevlar pads to prevent cuts from chain saws, and caulks (screw-in spikes) to prevent slips when working on logs or ice.

Rubber boots are recommended for tasks involving prolonged contact with water or whenever a risk of exposure to hazardous chemicals exists, such as pesticides. Just as when selecting rubber gloves, ensure the material is suitable for the exposure. To prevent water and chemicals from entering the top of the boot, place the coveralls *outside* the boot to shed water onto the ground.

A consideration that is often overlooked when using rubber boots is perspiration removal. Because rubber boots do not breathe, perspiration cannot readily escape, so the socks and feet will eventually be soaked with perspiration. Keeping the feet dry is essential for good health, so proper measures must be taken. Socks of polypropylene and cotton blends can help wick the moisture away, and moisture absorbent liners are available as well. Remove the boots and allow the feet to *breathe* and dry occasionally. To help prevent foot health problems always wash and dry the feet at the end of each day, allow footwear to dry and air out between uses, and begin each day with clean, dry socks.

15.2.4.6 Body Protection

The skin is your body's largest organ, and it performs a number of vital functions: keeping moisture in; sweating to cool your body; and keeping harmful agents from entering the body. Because the skin is exposed to so many hazards, it is important to protect it. The skin can adequately protect the body from many hazards (such as most bacteria), however, it can easily be penetrated or damaged by many chemicals. Another alarming fact is the increased incidence of skin cancers resulting from sun exposure. People who spend long hours in the sun are at increased risk of developing skin cancer unless they take protective measures.

Friction scrapes and cuts are also common sources of skin injuries and irritation. Properly selected clothing can prevent or minimize the chances of many skin disorders. *Normal* clothing can prevent many types of skin problems. For example, a light-colored long-sleeve shirt can protect the arms and upper body from sunburn and reduce the risks of skin cancers, and the long-sleeve shirt may actually be cooler than a short-sleeve shirt when working in the sun because it will reflect the sunlight. Other clothing that helps prevent sunburn and skin cancer includes a wide-brimmed hat to protect the ears, face, and neck, and long pants to protect the legs.

Coveralls should be made of a tightly woven fabric, such as cotton or polyester or of a nonwoven fabric. They should fit loosely. Unless there is a layer of air between the coverall and the skin, any chemical that gets through the coverall will be in direct contact with the skin. Each layer of clothing worn under the coverall adds not only a layer of material, but also a protective layer of air. Well-designed coveralls have tightly constructed seams and snug, overlapping closures that do not gap or become easily unfastened.

Rubber or chemical-resistant aprons are needed when handling liquids for prolonged periods of time, or when handling concentrated chemicals. Wear an apron even if other protective clothing is also being worn. Keeping the skin clean and dry is always important, but the groin area is especially sensitive. Chemicals can penetrate the skin of the groin area more than 11 times more readily than through the forearm (Figure 15-1). A splash of a concentrated chemical here could result in a high dose of toxins entering the body very quickly.

Choose an apron that extends from the neck to at least the knees. Some aprons have attached sleeves, which can also protect the arms. Be aware that an apron can be a safety hazard in some situations. It can get in the way or get caught in machinery. In these situations, consider wearing a chemical-resistant suit instead.

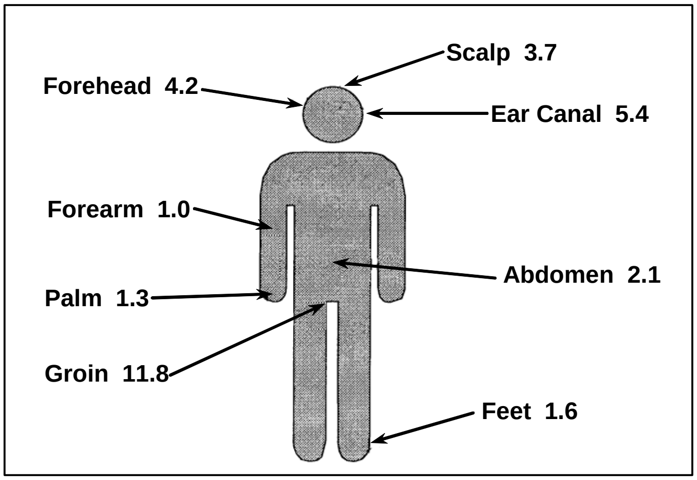

Figure 15-1. Absorption rates of chemicals through the skin of various parts of the body. Numbers are rates of absorption in comparison to the forearm.

Chemical-resistant suits are often disposable and are made from a variety of materials that provide varying levels of protection and comfort. They may be one-piece coveralls or two-piece outfits consisting of a jacket worn over overalls or pants. Chemical-resistant suits can be uncomfortably warm to wear. Take precautions to avoid overheating and heat stress. These garments should be disposed of when damaged or contaminated, especially if contaminated with concentrated chemicals.

15.2.4.7 Respiratory Protection

Warning
Use only respirators approved by the National Institute for Occupational Safety and Health or the Mine Safety and Health Administration for the hazards present in the workplace.

WWLA operators may be exposed to many irritating and potentially harmful airborne contaminants while working at a land application facility. Examples of air contaminants include particles of pollen, bacteria, mold spores, aerosols, hazardous chemicals, and engine exhausts. The respiratory system is one of the easiest ways contaminants can enter our bodies.

One problem with occupational illnesses is that the worker may not associate the illness with job-related exposures. Symptoms of respiratory illness may be mistaken for the flu, common cold, or simple exhaustion.

Another problem is that people may perform a particular task for years without experiencing adverse health effects, but suddenly experience a severe reaction to even slight exposures to contaminants. The body can become *sensitized* and no longer tolerate even small exposures to a substance. Additionally, some exposures can lead to permanent lung injury and disability.

Selecting and using a respirator involves more than simply purchasing one and putting it on. Using the wrong respirator, or using a respirator improperly, can result in serious illness or death. The respirator must be selected for the specific contaminants in your workplace, and it must fit properly. In addition, the respirator must be properly cleaned, inspected, and stored after each use to prolong its life and help ensure protection for later uses.

The best way to select a respirator is to consult an industrial hygienist or other similarly qualified professional. If respirators are needed, these professionals can assist with selection, fit testing, and training to use the respirator properly. Additionally, a written respiratory protection program must be developed that specifies how these tasks will be accomplished.

Two basic types of respirators are air-purifying respirators and air-supplying respirators.

- Air-purifying respirators remove contaminants from the air by filtering dust, mists, and particles or by removing gases and vapors. These respirators will not protect the WWLA operator from fumigants, from high concentrations of vapor, or when the oxygen supply is low. Several styles of air-purifying respirators are described below:
  - *Cup-style respirators* filter out dust, mists, powders, and particles. They are usually shaped filters that cover the nose and mouth.
  - *Cartridge respirators* are half-mask or full-face respirators that have chemical cartridges containing air-purifying materials. Many chemical cartridge respirators can be fitted with particulate prefilters. By using the proper cartridges and prefilters, it is possible to use chemical cartridge respirators in a variety of situations. Chemical cartridges are color-coded, so you can determine at a glance whether the correct respirator is in use. The cartridge needed depends on the particular contaminants present since different filter materials must be used for the various chemical hazards.
  - *Canister respirators* (gas masks) are full-face respirators with attached canisters containing air-purifying materials. Canisters usually contain more air-purifying materials than cartridge respirators. The face-piece is designed to be cleaned and reused. Canisters can be replaced.

  Air-purifying respirators pass air through the air-purifying material in two ways. Negative-pressure respirators depend on the wearer’s lungpower to draw air through the purifying material. Powered air-purifying respirators (PAPRs) assist the wearer by forcing air through mechanically. PAPRs purify contaminated air as it passes through the filter; they do not supply oxygen.
- Air-supplying respirators supply clean, uncontaminated air from an independent source. These respirators provide oxygen, and they can be used in oxygen deficient atmospheres, or atmospheres that are immediately dangerous to life or health.

Two types of air-supplying respirators are the *supplied-air respirator* and the *self-contained breathing apparatus* (SCBA).

- A supplied-air respirator provides breathing quality air from an approved air pump located in a safe atmosphere or from a remote tank of breathing air.
- SCBA supplies clean air from cylinders that are carried with the WWLA operator, usually on the back.

Air-supplied respirators must be inspected and tested regularly and should only be used by specially trained individuals; use by untrained persons could lead to serious injury or death.

15.3 Health and Safety Hazards

The WWLA operator may be exposed to numerous common hazards:

- Physical injuries (most common hazard)
- Infections and infectious diseases
- Oxygen deficiency
- Toxic or suffocating gases or vapors
- Chemical contamination
- Explosive gas mixtures
- Fire (least common hazard)
- Electrical shock
- Noise-induced hearing loss
- Dust, fumes, and mists
- Heat exhaustion and heat stroke

15.3.1 Health and Safety Measures

Numerous safety practices, training, and equipment serve as preventative measures and allow the WWLA operator to minimize the risk of the health and safety hazards listed in section 15.3:

- Process safety management and risk management programs
- Confined space safety
- General site safety
- Lockout/tagout policies
- Electrical safety
- Mechanical safety
- Vehicle safety
- Lagoon safety
- Fire prevention and protection
- Excavation and shoring safety
- Medical safety

15.3.2 OSHA Process Safety Management and EPA Risk Management Programs

The OSHA Process Safety Management and EPA Risk Management programs regulate how certain highly hazardous chemicals are to be used, stored, or manufactured. The goal of both programs is to prevent accidental releases of the substances that can cause serious harm to the public and environment. If you store or have on site at any one time more than a *threshold quantity* of the chemicals listed in Table 15-1, then a process safety program and/or a risk management program may be needed. EPA and OSHA have slightly different listings and slightly different threshold quantities, and exemption from one program does not necessarily mean exemption from the other. Generally, if a facility uses the chemicals in the amounts listed in Table 15-1, the facility will need to develop a program. Specific information on the OSHA program can be found in "Process Safety Management of Highly Hazardous Chemicals" (29 CFR 1910.119), and specific information on the EPA program can be found in "Chemical Accident Prevention" (40 CFR 68).

Table 15-1. Threshold quantities for chemicals requiring a process safety program or risk management program.

Chemical	EPA Threshold Quantity (lb)	OSHA Threshold Quantity (lb)
Chlorine	2,500	1,500
Anhydrous ammonia	10,000	10,000
Aqueous ammonia	> 20% 20,000	> 44% 15,000
Anhydrous sulfur dioxide	5,000	1,000 (liquid)
Methane	10,000	10,000
Propane	10,000	10,000

Notes: United States Environmental Protection Agency (EPA); Occupational Safety and Health Administration (OSHA); pound (lb)

15.4 Confined Space Safety

Two types of confined spaces are defined as follows:

1. A *confined space* has limited means of access (entry) and egress (exit), has an adequate size and configuration for employee entry, and is not designed for continuous worker occupancy.
2. A *permit-required confined space* requires a permit for entry, may have a potentially hazardous atmosphere, may have an engulfment hazard, may have an entrapment hazard, or may contain any other recognized hazard.

If a facility has permit-required confined spaces, a written confined space entry program must be developed and implemented to be in compliance with OSHA regulations. Enclosed facilities such as tanks and/or tanker trucks, would fall under the permit-required confined space regulations.

Warning
Do not enter a permit-required confined space without proper training, equipment, and support personnel. Confined space regulations are found in "The Control of Hazardous Energy (Lockout/Tagout)" (29 CFR 1910.147).

The atmosphere of a confined space may be extremely hazardous because of the lack of natural ventilation. This can result in the following dangerous situations:

- Oxygen-deficient atmospheres
- Flammable atmospheres
- Toxic atmospheres

An *oxygen-deficient atmosphere* has less than 19.5% available oxygen (Figure 15-2). Any atmosphere with less than 19.5% oxygen should not be entered without an approved SCBA. Oxygen-deficient atmospheres may be found in sewers, manholes, septic tanks, and pump tanks.

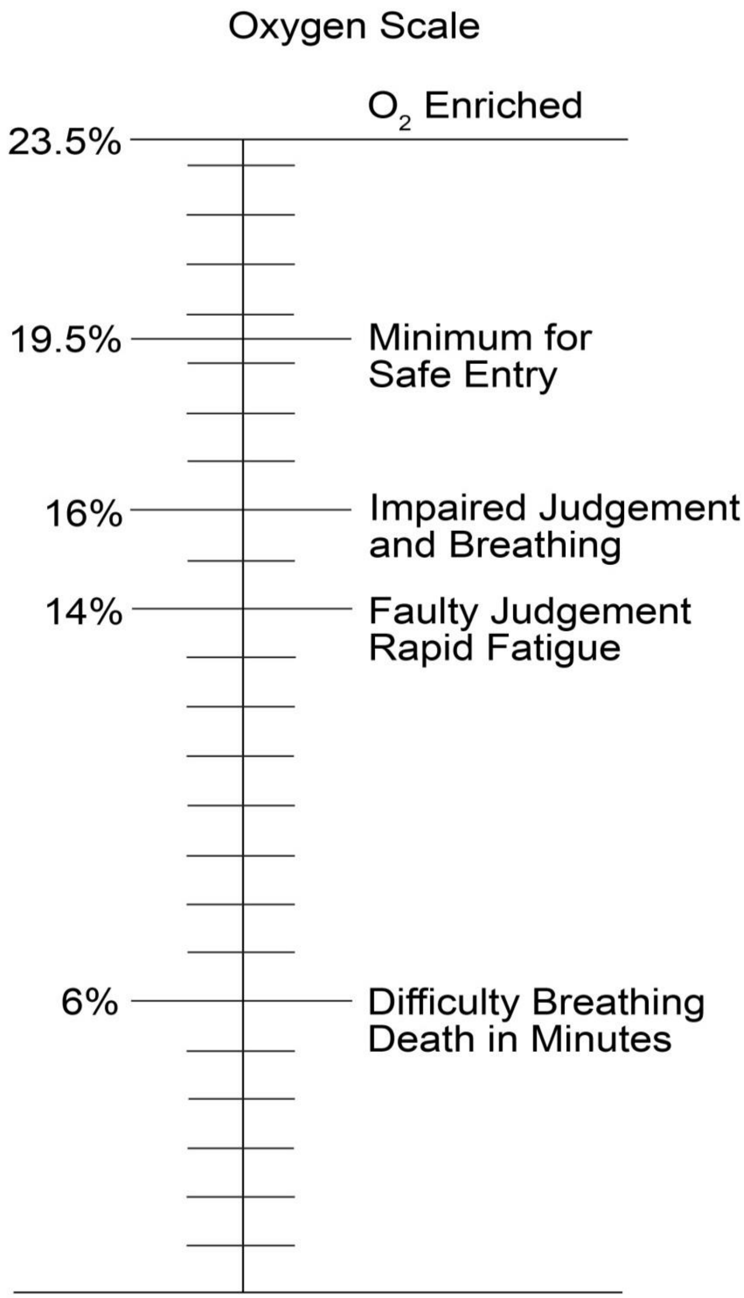

Figure 15-2. Oxygen scale (N.C. DL 1993).

When working in a confined space that does not require a permit, the following safety actions must be taken:

- Use a ladder, hoist, or other device when accessing these work areas.
- Verify that the confined space is clean and well ventilated. Test the atmosphere of the space, from the top of the work space to the bottom, for flammable/toxic gases and oxygen deficiencies *prior* to entering the work space, and repeat testing during the work period.
- Use lifelines and always assign a standby person to remain on the outside of the confined space. It is the standby person's responsibility to be in constant contact (visually and/or verbally) with the workers inside the confined space as long as anyone is in the space.
- Wear ear protection, as needed. Noise within a confined space can be amplified because of the design and acoustic properties of the space.
- Be mindful of the possibility of falling objects when working in confined spaces.
- SCBA should be used in confined spaces where oxygen is insufficient.

15.5 General Site Safety

A land application site should be restricted to authorized personnel. This restriction is necessary to prevent mishaps involving the public and to ensure that the site and all equipment are protected from vandalism and theft.

Maintaining the land application site promotes a safe, well-kept working environment. Site maintenance includes the following:

- Keep walks, aisles, and access ways clear of tools and materials. Maintain clear access to electrical panels, control valves, and fire extinguishers.
- Clean up puddles of oil, sludge, or fuel promptly and thoroughly. Use absorbent material if necessary.
- Dispose of dirty and oily rags, used absorbent materials, trash, and other waste materials in approved containers. The waste should be removed from the site and disposed of properly.
- Provide scrap containers or scrap collection area where needed.
- Keep the sanitary facilities clean.
- Keep supply areas organized and free of hazards.
- Provide adequate illumination and ventilation.

15.5.1 Lockout/Tagout Policy

A *lockout* is a padlock placed on a power source to block the release of hazardous energy that could set a machine in motion or otherwise endanger an employee working on the machine. Locks are usually used with a lockout device that holds an energy control point, such as a switch lever or valve handle in the *off* position, preventing machines or equipment from being operated while the machine is being worked on.

A *tagout* is a written warning that tells other workers not to operate a switch or valve that could release hazardous energy or set a machine in motion. Lockout is preferred because it is a more secure method of controlling and isolating hazardous energy sources. Although lockout/tagout policies most commonly refer to electrical energy, the following types should also be covered:

- Mechanical
- Hydraulic
- Pneumatic
- Stored
- Chemical
- Thermal

A written lockout/tagout program should be developed that specifies how individual machines or equipment will be taken out of and returned to service. Once the program has been developed, all employees who use or perform maintenance on any of the affected equipment must be properly trained. Lockout/tagout procedures are frequently used measures to minimize hazards at a land application facility.

15.5.2 Electrical Safety

Treat all electricity and electric power equipment with caution: ordinary 120 volt (V) electricity can be fatal. Most systems operate from 120 V to 4,000 V, or more.

In case of electrocution, turn off power to the electrical source or use an insulated implement, such as a piece of wood to separate the person from the source. Do not attempt to pull a victim away from the electrical source with your bare hands. The following is a list of general electrical safety practices (WEF 1996):

- Allow only qualified and authorized personnel to work on electrical equipment and wiring or to perform electrical maintenance.
- Provide and use lockout devices and tags at all locations.
- Always assume electrical equipment and lines are energized unless they are positively proven to be de-energized and properly grounded. If the equipment is not grounded, it is not dead.
- Prohibit use of metal ladders or metal tape measures around electrical equipment.
- Ensure that two people always work as a team on energized equipment.
- Use approved rubber gloves on voltages more than 300 V.
- Do not open an energized electrical control panel.
- Before work is done on a line or bus that operates at 440 V or higher, ensure it is de-energized, locked out, and grounded in an approved manner.
- Do not test a circuit with any part of the body.
- Prevent grounding by avoiding body contact with water, pipes, drains, or metal objects while working on electrical equipment or wiring.
- Do not bypass or render inoperative any electrical safety devices.
- When working in close quarters, cover all energized circuits with approved insulating blankets.
- Use only tools that have insulated handles.
- Never use metal-cased flashlights.
- Do not wear jewelry when working with or near electric circuitry.
- Ground or double-insulate all electrical tools.

- Use rubber mats at control centers and electrical panels.
- Always keep electric motors, switches, and control boxes clean.

15.5.3 Mechanical Safety

Mechanical safety guidelines apply to land application equipment, pressure-vacuum equipment, and hydraulic systems.

15.5.3.1 Land Application Equipment

Keep the following in mind when working on land application equipment:

- Ensure that sprinklers, guns, hydrants, valves, and plugs are not pressurized or electrically energized when servicing or repairing land application equipment. Pressurized or energized equipment can cause serious injury or death.
- When servicing, turn pumps off and depressurize lines by opening drain valves or opening discharge points to relieve water pressure.
- If you must clean a nozzle, operate an isolation valve and clean the nozzle when not under pressure.
- Use the proper tools when working in valve boxes.
- Valve boxes can be pinch points and are favorite havens of spiders and snakes, so be alert!
- Equipment such as traveling guns and center pivots (tractors) have many pinch points and moving parts and are energized with high voltage electricity. Keep equipment guards in place, tie back long hair, and do not wear loose clothing when operating this type of equipment. Use lockout/tagout procedures when working on this equipment.
- Be familiar with operational parameters from manufacturers' literature.
- Have a qualified electrician install and service all electrical systems for this type of equipment.
- Operating traveling guns (or hard-hose travelers) on steep and complex terrain can present safety concerns. Slopes up to 15% (and possibly slightly higher) can be effectively managed with traveling guns. However, the guns should be traversed across the slopes in an *up and down* fashion as opposed to pulling the gun sideways across the slope. If the gun is pulled sideways across the slope, the potential for a flipped gun cart with the associated tractor and operator is much greater. Should a gun cart flip, the system continues to apply recycled water from whatever position the sprinkler gun is in, creating a safety hazard.
- Gun carts typically have an adjustment that allows the wheel or track width to be increased. The widest footprint possible should be used on sloping terrain.
- Side slopes above 8% should be avoided if a sideways pull must be used.
- Travel lanes for gun carts should be inspected for steeply sloping areas, gullies, tree roots, rocks, or any other disturbances in a field. These disturbances can potentially cause the gun cart to come off track or flip over. Correct these situations or select another travel lane to use the field safely.
- Machine guarding: Any machine part, function, or process that may cause injury must be safeguarded. Safeguards are needed in the following locations:

    - At the point of operation, where the machine contacts the material and performs operations, such as cutting, punching, grinding, boring, forming, or assembling.
    - Near power transmission components such as pulleys, belts, connecting rods, cams, chains, sprockets, cranks, and gears
    - At other parts of the machine that move (rotation, reciprocating movement, transverse movement) while the machine is working.
- Operate machinery only if trained and authorized to use it.
- Do not wear jewelry on the job.
- While gloves are recommended for many tasks, do not wear them in situations where they could get caught and draw you into a machine.
- Do not try to adjust or reposition material while a machine is running.
- Wear the appropriate PPE equipment.
- Operate machinery with the safeguards in place. Report missing or damaged safeguards to the site supervisor.

15.5.3.2 Pressure and Vacuum Equipment

The proper venting of storage tanks is imperative. Pressure relief valves must be kept in good working condition. The following venting procedures should be used when operating equipment:

1. Vent tank (so there is no pressure or vacuum) by opening hatches or manholes.
2. Do not go on top of a tank when it is under pressure, as the pressure relief valve can operate at any time.
3. When opening a pressurized tank's manhole cover after the pressure has been relieved, open the clamping devices next to the hinge first. Open the clamp with the safety catch last.
4. Relieve the pressure in the hose before disconnecting it to avoid possible injury from unrestrained action of the hose.
5. Do not restrict or block off safety valves or blow-down lines.
6. The accumulation of gases within a confined space offers the potential for the vessel to explode or relieve the pressure at a weak point. *Always* stay to the side of all covers when opening. *Never* stand with your head or body over the cover when opening.

15.5.3.3 Hydraulic Systems

When working on hydraulic systems, observe the following guidelines:

1. Do not open pressurized lines. Hydraulic fluid can cause severe burns, eye injury, or skin irritation.
2. Search for leaks in the line using a piece of cardboard or wood, not your hands.
3. If anyone is injured by hydraulic fluid: administer first aid; then contact a physician.
4. Stay clear of leaky hydraulic lines.

15.6 Land Application Site Vehicle Use

Only employees with a current, valid Idaho driver's license should drive vehicles. In the case of specialized vehicles, only trained operators should operate the vehicles. When operating heavy equipment vehicles and heavy over-the-road vehicles, observe the following rules:

- Ensure everyone is clear of the vehicle before starting.
- Slight steering movement can occur as the engine starts, causing machine movement. Stay clear of the engine when it is running.
- Work on the engine only when it is off.
- Carefully inspect trucks or trailers before moving to ensure that material and equipment are properly loaded and secure.
- Loads on trucks and trailers should not exceed rated capacities.
- Securely couple trailers to the towing vehicle when towing.
- Secure all trailers with safety chains or cables, except those attached to a tractor by a *fifth wheel*.

15.6.1 Heavy Off-The-Road Vehicle Operation

When operating heavy off-the-road vehicles, observe the following guidelines:

- Drive at a safe, legal speed to ensure safety and complete control of the vehicle, especially over rough terrain.
- Unless the vehicle is designed for more than one person, no one other than the operator should be on the vehicle.
- Always observe the speed limits of local landowners.
- Yield the right-of-way to local trucks and local road maintenance machinery.
- Use chock blocks on the tractor and trailer when the driver leaves the vehicle.

15.7 Lagoon Safety

When working on or around a lagoon, at minimum, observe the following safety guidelines:

- Never go out on the lagoon to sample, or for other purposes, by yourself. Another worker should always be standing by in case of emergency.
- Always wear an approved life jacket when you are working from a boat on the surface of the lagoon.
- Never stand up in a boat while performing work.
- If it is necessary to drive a vehicle on a dam, ensure the roadway is maintained and is in good driving condition. Be extremely cautious when driving on dams during wet weather.
- Routinely inspect and fix potholes, ruts, and rodent tunnels in berms or dams
- If you must walk on the inside sideslope, you should be harnessed and attached to prevent sliding into the lagoon.

15.8 Fire Prevention and Protection

It is important to be fire-conscious in the outdoor environment. Employees should be knowledgeable of the fire conditions at the site and operate accordingly. Poor site maintenance, worn or defective electrical systems, and welding and cutting may contribute to dangerous situations. The following precautions should be observed:

- Do not smoke near equipment or fuel trailers.
- Do not allow open flame near wastewater storage areas.
- Do not allow wastepaper, rags, and other combustible materials to accumulate.

- Do not tamper with, or remove, fire-fighting equipment from designated locations for purposes other than firefighting or rescue operations.
- Do not hinder access to fire equipment.
- Promptly recharge fire extinguishers if they are used.
- Inspect fire extinguishers monthly to ensure they are in good operating condition.

15.9 Medical Safety

Medical safety at land application sites needs to address several areas, including first aid, pathogen awareness, eyewash stations, immunization, personal hygiene, and safety lifting and carrying activities.

15.9.1 First Aid Training

A person with first aid training should be present, or available at all times. If the land application site is more than 15 minutes away (including transport time) from a clinic, hospital, or physician, OSHA requires a designated person qualified in first aid and cardiopulmonary resuscitation training to be present at all times. The training should include but not be limited to the following:

- Bleeding control and bandaging
- Artificial respiration, including mouth-to-mouth resuscitation
- Poisons
- Shock, loss of consciousness, and stroke
- Burns
- Heat stress and heat stroke
- Frostbite and hypothermia
- Strains, sprains, and hernias
- Fractures and dislocations
- Bites and stings
- Transportation of the injured
- Specific health hazards likely to be encountered by coworkers

Adequate first aid kits and supplies should be on site and readily available. A list of all employees with first aid qualifications should be posted, along with a list of emergency telephone numbers.

15.9.2 Blood-Borne Pathogen Awareness

All workers at a land application facility should be aware of the potential for contracting a blood-borne disease, such as hepatitis A or tetanus. *Human immunodeficiency virus* (HIV) is also considered a blood-borne pathogen and precautions should be taken when in direct contact with wastewater or sewage. One study has shown that HIV can survive in wastewater for up to 12 hours. OSHA requires an employer to provide specific training and PPE for your job if a blood-borne pathogen exposure is expected by job classification. Components of such a program include the following:

- Safe work practices
- Use and care of PPE

- Housekeeping
- Employee training
- Incident reporting
- Employee medical monitoring

15.9.3 Eyewash Stations

Suitable facilities for quick drenching or flushing of the eyes and body should be provided in areas where the eyes or body of any person may be exposed to injurious chemicals and materials. Eyewash equipment can either be portable or permanently installed. Both styles of dispensers allow a gentle trickle of water to flow across the eye.

If someone's eyes have been exposed to a chemical, such as chlorine gas, the eyes should be flushed for at least 15 minutes to dilute and remove as much of the chemical as possible.

Medical professionals should be consulted for any eye injury.

15.9.4 Immunization

Each facility may want to consult a physician or the local health district to determine the need for immunizations for the employees working at the site. Adult tetanus and diphtheria should be given routinely every 10 years, or at shorter intervals when injury occurs.

15.9.5 Personal Hygiene

Because recycled water may contain pathogens, good personal hygiene is very important to reduce exposure. Good personal hygiene includes the following:

- Keep your hands away from your nose, mouth, eyes, and ears to avoid ingestion.
- Wear protective clothing (such as nonpermeable gloves) when handling any equipment covered with recycled water.
- Take special care (e.g., protective, waterproof dressing) to keep any area of broken skin covered to avoid possible infection. If a worker suffers an injury that results in an open wound or laceration, they should be given a tetanus booster.
- Wash hands thoroughly with soap before smoking, eating, drinking, or after work.
- Change and wash work clothing daily.
- Wash any areas that come into contact with recycled water thoroughly with water and soap.
- Sponge any cuts with an antiseptic solution and covering with a clean, dry gauze dressing, and waterproof adhesive.

15.9.6 Safe Lifting and Carrying Techniques

Everyone should observe the following guidelines to avoid possible injury when lifting and carrying objects:

- Test the load first and do not move more than is comfortable.
- Set your feet far enough apart to provide good balance and stability (approximately the width of your shoulders).

- Get help for large, bulky, or heavy items.
- Get as close to the load as practical, and bend your legs about 90 degrees at the knees.
- Straighten your legs to lift the object, and, at the same time, bring your back to a vertical position. Use your legs to lift rather than your back.
- Never carry a load that blocks forward vision.
- To lower the object, repeat the stance and position for lifting; bend the legs to 90 degrees and lower the object.
- When lifting an object with another person, ensure that both individuals lift at the same time and put the load down together.

15.10 Public Health and Safety

In addition to protecting the health and safety of employees, coworkers, and themselves, permittees and WWLA operators also have a responsibility to protect the health and safety of the public.

The general public is often unaware of the dangers associated with a land application facility, so a land application site should be restricted to authorized personnel to prevent exposure of the public to physical injuries and accidents and possible contamination from pathogens and *vectors* (animals or organisms capable of transporting infectious agents).

By properly operating and maintaining the system (thereby reducing the risk of spills, overflows, excessive drift, and runoff), the WWLA operator reduces the risk of contaminating ditches, waterways, and adjoining properties. This, in turn, protects the public from contact with contaminated surface waters or ground water. If spills or discharges do occur, rapid mobilization of a well-thought out and well-practiced emergency response plan can minimize the health and safety threat to the public. Proper operation of a land application site should result in a minimal level of health risk to those living on property adjoining the site who may experience at times low levels of exposure during normal operating conditions.

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16 Idaho Rules and Requirements

Need-to-Know Criteria
“Recycled Water Rules” (IDAPA 58.01.17) and “Wastewater Rules” (IDAPA 58.01.16): permit review, reuse facility plan of operations, permit renewals, entry and access, permit requirements, compliance with permit conditions, noncompliance reports, permit modifications, and penalties for permit violations
“Ground Water Quality Rule” (IDAPA 58.01.11)
“Wastewater Rules” (IDAPA 58.01.16) and “Rules of the Board of Drinking Water and Wastewater Professionals” (IDAPA 24.05.01) as related to wastewater operator requirements.

The WWLA operator must know the rules and how they apply to the reuse site. DEQ promulgates statutory rules and has permitting authority for reuse of recycled water. This section discusses the Idaho rules related to land application of recycled water, which the WWLA operator must become familiar.

- Recycled Water Rules (IDAPA 58.01.17)—Establish the procedures and requirements for issuing and maintaining reuse permits. These rules also require that systems meeting the definition of a public wastewater system be classified based on indicators of potential health risk.
- Wastewater Rules (IDAPA 58.01.16)—Establish the procedures and requirements for planning, designing, and operating wastewater facilities, discharging wastewaters, and human activities that may adversely affect public health and water quality in the waters of the state.
- Ground Water Quality Rule (IDAPA 58.01.11)—Establishes minimum requirements for protection of ground water quality through standards and an aquifer categorization process. These rules apply to all activities that have the potential to degrade ground water. The activities need to be managed in a way to maintain or improve the ground water quality.
- Water Quality Standards (IDAPA 58.01.02)—Designate uses that are to be protected in the waters of the state and establish standards of water quality protective those uses. Restrictions are placed on discharge of wastewaters and on human activities that may adversely affect public health and water quality in the waters of the state.
- Rules of the Board of Drinking Water and Wastewater Professionals (IDAPA 24.05.01)—Contain the specific requirements for operator licensure. The law requires wastewater operators to be licensed by the Board of Drinking Water and Wastewater Professionals (board) through the Idaho Board of Occupational Licensing (IBOL) in order to operate, offer to operate, be in responsible charge of, or to otherwise serve as operating personnel at any public wastewater system.

IDAPA 58.01.02, 11, 16, and 17 can be viewed under the DEQ Idaho Administrative Rules website: *http://adminrules.idaho.gov/rules/current/58/index.html.*

IDAPA 24.05.01 can be viewed under Occupational Licenses at the Idaho Administrative Rules website: *http://adminrules.idaho.gov/rules/current/24/index.html.*

16.1 Recycled Water Rules (IDAPA 58.01.17) and Wastewater Rules (IDAPA 58.01.16)

The WWLA operator should understand the rules that govern the treatment and beneficial use of recycled water. The "Recycled Water Rules" (IDAPA 58.01.17) and "Wastewater Rules" (IDAPA 58.01.16) both have requirements for recycled water treatment and land application sites. In addition, the "Ground Water Quality Rule" (IDAPA 58.01.11) direct the operator regarding the protection of ground water resources.

IDAPA 58.01.17 governs the permitting at land application sites and specifies that no person shall construct, modify, operate, or continue to operate a reuse facility without a valid permit issued by DEQ. IDAPA 58.01.17 also specifies the application process for a reuse permit and includes components that are addressed in IDAPA 58.01.16.

16.1.1 Application Process for Reuse Permits

A detailed review of the process involved in applying for and receiving a reuse permit is beyond the scope of this manual; many WWLA operators may never be involved in this process but should understand the basic time lines. The following provides an overview of the process for obtaining a permit for a new facility, an expanding facility, or a permit renewal for an existing facility.

16.1.1.1 Permit Review

DEQ, which has statutory rules and permitting authority, reviews permit applications and issues all reuse permits. All applications must be submitted to DEQ with the required information, as listed in IDAPA 58.01.17.300.03. Prospective applicants are encouraged to meet with DEQ prior to submission of an application to discuss the application procedure and anticipated application requirements. To allow for adequate processing time, all applications are required to be submitted 180 days prior to anticipated use or prior to the expiration date on the existing permit.

The PO (reference section 4.1) should accompany the reuse application for all existing systems. All new systems that include lift stations or treatment works are required to provide a final PO to DEQ for review and approval prior to start-up of the proposed system unless the system components are already covered in an existing PO. All land application facilities are required to keep the PO updated to reflect current operations

16.1.1.2 Notice of Completeness or Incompleteness

Within 30 days after an application is received by DEQ, a notice of application completeness or incompleteness is issued. If the application is determined to be complete, DEQ will issue a *notice of completeness*, including the effective date of the application—which is the date of the notice—and a project schedule for processing the permit, with anticipated dates for (1) the preliminary permit decision to prepare a draft permit or permit denial and (2) the issuance of the final permit. If the application is determined to be incomplete, DEQ will specify deficiencies in the application and request additional information.

16.1.1.3 Preliminary Decision

Within 30 days of the effective date of the application, DEQ will issue the preliminary decision to prepare a draft permit or issue a permit denial. If the permit is denied, a staff analysis will be provided that covers the conditions for denial with references to supporting documents and materials.

16.1.1.4 Draft Permit and Staff Analysis

Within 60 days of issuing the preliminary decision to prepare a draft permit, DEQ shall issue a draft permit and staff analysis. The staff analysis is a document that briefly states the principal facts and significant questions considered in preparing the draft permit.

After the draft permit is issued, the draft permit and staff analysis are placed on DEQ's website for a public comment period. After all comments from the public and applicant are addressed, a final permit is issued to the permittee. Reuse permits are issued for a fixed term of not more than 10 years.

16.1.2 Permit Renewals

Prior to the expiration of an existing permit, a permit renewal application must be submitted to DEQ. This application must be submitted 180 days prior to the permit expiration date to allow for processing time.

16.1.3 Plans and Specification Review

The WWLA operator should know that anytime a construction change or major modification to the land application site or facility occurs, DEQ must be notified, and often a plan and specification review is required.

Prior to the construction or modification of reuse facilities associated with a land application system, detailed plans and specifications, prepared by an Idaho-licensed professional engineer, must be submitted to DEQ for review and approval. The plans and specifications shall follow IDAPA 58.01.17, IDAPA 58.01.16, the guidelines in the *Recommended Standards for Wastewater Facilities (Ten State Standards)* (State of New York 2004), the *Idaho Standards for Public Works Construction* (ISPWC 2012), and the *Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater* (DEQ guidance) (*www.deq.idaho.gov/media/516329-guidance_reuse_0907.pdf*).

Within 30 days after construction, and prior to operation of the facilities, the permittee must submit to DEQ either (1) a certification from a professional engineer certifying that construction was completed in accordance with the DEQ-approved plans and specifications or (2) as-built plans for DEQ review and approval.

16.1.4 Entry and Access

The permittee and/or WWLA operator shall allow any DEQ representative, upon presentation of credentials and with the owner's permission, to inspect any land application system at any reasonable time for the purpose of determining compliance with the system permit. DEQ representatives may inspect or copy any records that must be maintained under the terms and conditions of the permit and may obtain samples of ground water, surface water, or effluent.

Inspections are conducted under the direction of DEQ regional office staff. These inspections occur prior to the initial operation of the system, prior to operation of a monitoring well, prior to the renewal of the permit, and periodically in between these events. Systems that are out of compliance may be inspected on a more frequent basis.

16.1.5 Monitoring and Reporting Requirements

The permittee shall submit reports and monitoring results to DEQ as specified in the reuse permit. These reports are typically submitted on an annual basis but can be required on a monthly basis or some other frequency. The permit will specify which parameters to monitor, when to monitor, and when results must be submitted. Monitoring may include recycled water monitoring, soil and plant tissue analyses, and ground water or surface water monitoring.

16.1.6 Permit Requirements

A reuse permit addresses the compliance needs and operational requirements of the system. It is also a legal and binding agreement and is enforceable by law. Therefore, it is extremely important for the permittee to maintain a copy of the permit and to be familiar with and fully understand the conditions of the permit.

It is the permittee's responsibility to ensure that the system is properly operated, properly maintained, and is in compliance with permit conditions and requirements. Ultimately, it is the permittee who is responsible for any violation of a permit condition or requirement, regardless of who is actually operating the system.

If the system is operated by someone other than the permittee (which is often the case), it is extremely important that the WWLA operator also be familiar with and fully understand the conditions and requirements of the permit. The WWLA operator must understand the permittee’s legal responsibilities and keep the permittee informed concerning the daily operation of the plant. If any problems occur with operations or equipment, the WWLA operator must notify the permittee so decisions can be made and problems can be corrected.

16.1.6.1 Compliance with Permit Conditions

All permit conditions and requirements are important in the operation of a land application system. Examples of typical municipal reuse permits are included in Appendix A.

The permittee or designee should conduct regular inspections of the land application system, as part of the system operation and maintenance, to prevent malfunctions, deterioration, and WWLA operator errors that lead to unpermitted discharges. An inspection log should be maintained throughout the life of the permit and should be accessible for immediate reference, along with the permit and PO. Maintaining an inspection log is important because it provides needed information on land application components and the need for maintenance or repair.

Permittees or WWLA operators are encouraged to request technical assistance from the DEQ regional office for help with problems that may result in noncompliance with permit conditions or requirements.

16.1.6.2 Noncompliance Reports

If an action of noncompliance with permit conditions or requirements occurs, this occurrence must be reported to DEQ. The permittee must report orally to the appropriate DEQ regional office as soon as possible, but in no case more than 24 hours from the time the permittee became aware of any noncompliance that may endanger public health or the environment.

The permittee shall report in writing, as soon as possible but within 5 days of the date the permittee knows or should know of any noncompliance, unless extended by DEQ. This report shall contain the following:

1. A description of the noncompliance and its cause
2. The period of noncompliance, including, to the extent possible, times and dates, and, if the noncompliance has not been corrected, the anticipated length of time it is expected to continue
3. Steps taken or planned, including time lines, to reduce or eliminate the continuance or reoccurrence of the noncompliance

The permittee shall report to DEQ, in writing, as soon as possible after becoming aware of relevant facts not submitted or incorrect information submitted in a permit application or any report to DEQ. The facts or the correct information shall be included in the report.

The permitttee shall take all necessary actions to eliminate and correct any adverse impact on public health or the environment resulting from permit noncompliance.

16.1.7 Permit Modifications

Permit modifications can be categorized as minor or major modifications. Minor modifications are those, which if granted, would not result in any increased hazard to the environment or public health. Such modifications shall be made by DEQ. Minor modifications are normally limited to the following:

- Correcting typographical errors
- Transferring ownership or operational control
- Changing monitoring or reporting frequency

All modifications not considered minor are considered to be *major modifications*. The procedure for applying for a major modification is the same as that used for a new permit. Examples of major permit modifications include the following:

- Increase in flow that exceeds the conditions of the current permit
- Add reuse fields
- Add treatment components to the facility

A modification is *not* required for replacing components with like parts.

Permits may be transferred to a new owner or WWLA operator provided that the permittee notifies DEQ by requesting a minor permit modification before the transfer date.

All system modifications must be approved prior to the initiation of the modification. For questions about what is considered a modification, check with DEQ *before* any action is taken.

The permittee shall report to DEQ within 30 days before any planned physical alteration or addition to the permitted facility if the alteration or addition would result in a significant change in information submitted during the permit application process or would result in noncompliance with any permit condition or with IDAPA 58.01.17.

Whenever a facility expansion, production increase, or process modification is anticipated that will result in a change in the character of pollutants to be discharged, or which will result in a new or increased discharge that will exceed the conditions of the current permit, or if it is determined by DEQ that the terms or conditions of the permit must be modified to adequately protect public health or the environment, an application for a major permit modification must be submitted to DEQ, together with plans and specifications for the proposed change. Plans must be reviewed and approved by DEQ, and the new permit or permit modification must be issued prior to implementing the proposed change.

16.1.8 Permit Revocation

DEQ may revoke a permit if the permittee violates any permit condition or violates federal, state or local rules. Except in emergencies, DEQ shall issue a written *notice of intent to revoke* to the permittee prior to final revocation. Revocation shall become final within 35 days of receipt of the notice by the permittee, unless within that time the permittee requests an administrative hearing in writing. The hearing shall be conducted in accordance with the “Rules of Administrative Procedure Before the Board of Environmental Quality” (IDAPA 58.01.23).

If DEQ finds the public health, safety, or welfare requires emergency action, DEQ shall incorporate findings in support of such action in a written notice of emergency revocation issued to the permittee. Emergency revocation shall be effective upon receipt by the permittee. Thereafter, if requested by the permittee in writing, the director shall provide the permittee a revocation hearing and prior notice thereof. Such hearings shall be conducted in accordance with IDAPA 58.01.23.

16.1.9 Penalties for Permit Violations

Any person violating any provision of IDAPA 58.01.17, or any permit or order issued thereunder, shall be liable for a civil penalty not to exceed $10,000 or $1,000 for each day of a continuing violation, whichever is greater. In addition, pursuant to “Environmental Quality–Health (Idaho Code §39-1), any willful or negligent violation may constitute a misdemeanor.

16.1.10 Waivers

Waivers are not common. Waivers from the requirements of IDAPA 58.01.17 may be granted by DEQ on a case-by-case basis upon full demonstration by the person requesting the waivers that such activities for which the waivers are granted will not have a detrimental effect upon existing water quality and beneficial uses are adequately protected.

16.2 Ground Water Quality Rule (IDAPA 58.01.11) and Water Quality Standards (IDAPA 58.01.02)

In the context of this manual, the "Ground Water Quality Rule" (IDAPA 58.01.11) pertains to ground water impacts from the land application to the ground waters of the state. The WWLA operator should understand that IDAPA 58.01.11 influences the permit monitoring and limits for the land application site. IDAPA 58.01.11.200 and 301 identify minimum levels of protection for ground water quality (maximum acceptable levels for contaminants in ground water) and are used as a basis for evaluating or comparing ground water quality—when developing or modifying BMPs, identifying permit conditions, establishing cleanup levels, and determining appropriate actions when ground water quality standards are exceeded. The rule is intended to prevent degradation of the ground water beyond a level suitable for its intended best usage. Most of the standards are health-based, although the standards do recognize properties, such as taste and odor, which are nonhealth related but define suitability. Tables II and III in IDAPA 58.01.11.200 define the constituent standards for drinking water.

Numerical ground water quality standards for constituents typically of interest at land application facilities include the following:

- Nitrate (as N): 10 mg/L
- Total coliform: 1 colony forming unit/100 mL
- Chloride: 250 mg/L
- TDS: 500 mg/L

Although these numerical constituent standards are specified in IDAPA 58.01.11, the rule states that all activities must maintain or improve the existing high quality of the ground water and avoid significant impacts to the ground water.

In the context of this manual, the "Water Quality Standards" (IDAPA 58.01.02) pertain to surface water impacts from the land application to the surface waters of the state. The WWLA operator should understand that discharges and runoff from the reuse site will create a need for a federal NPDES permit. Without an NPDES permit, the reuse site must be managed so that discharges and runoff do not occur.

16.3 Wastewater Rules (IDAPA 58.01.16) and IDAPA 24.05.01 as related to Wastewater Operator Requirements

The "Wastewater Rules"(IDAPA 58.01.16.203), govern the requirements for public wastewater systems to have licensed operating personnel as well as requiring the permittee to designate licensed operators to be responsible for system operation. Pertinent definitions in IDAPA 58.01.16.010 and IDAPA 24.05.01 include the following:

- *Responsible charge*—Active, daily on-site or on-call responsibility for the performance of operations or active, on-going, on-site, or on-call direction of employees and assistants.
- *Responsible charge operator*—An operator licensed at a class equal to or greater than the classification of the system and designated by the permittee to have direct supervision of and responsibility for performing the operations of a specified wastewater treatment

system and directing personnel employed or retained at the same system. The responsible charge operator has an active daily on-site or on-call presence at the specified facility.
- *Substitute responsible charge operator*—A public wastewater operator holding a valid license at a class equal to or greater than the public wastewater system classification, designated by the permittee to replace and to perform the duties of the responsible charge operator when the responsible charge operator is not available or accessible.
- *Operating personnel*—Any person who is employed, retained, or appointed to conduct the tasks associated with the day-to-day operation and maintenance of a public wastewater system. Operating personnel shall include every person making system control or system integrity decisions about water quantity or water quality that may affect public health.

16.3.1 Designation and Responsibilities of the Responsible Charge Operator

The permittee is required to designate the *responsible charge* operator. The responsibilities of the designated responsible charge operator of a land application system include the following:

- Possess a current, valid wastewater treatment system operator license, class 1 or higher and at a class equal to or greater than that of the system.
- Possess a current, valid land application system operator license.
- Visit the system daily or be on-call daily to ensure the proper operation of the system.
- Operate and maintain the system efficiently and attempt to ensure compliance of the system with any permit issued for the system.
- Document the operation, maintenance, and all visitation of the system.
- Notify the permittee, in writing, of any needed repairs or maintenance necessary to ensure the compliance of the system.
- Be available for consultations and emergencies and provide access to the system by regulatory agencies.

The responsible charge operator must have detailed working knowledge of the DEQ-issued reuse permit and the system to maintain compliance with the facility permit conditions and state rules. Copies of the reuse permit and approved plans and specifications should be kept on site at all times. Phone numbers of DEQ contacts and the design engineer for the system should be available to address questions as they arise.

16.3.2 Responsibilities of a Substitute Responsible Charge Operator

A permittee designated *substitute responsible charge* operator must be available when the responsible charge operator is not available. Acting as the responsible charge operator, the substitute responsible charge operator must possess appropriate licensure and fulfill the requirements of the responsible charge operator as listed in section 16.3.1.

16.3.3 Responsibilities of Contract Operators

Any contract operator or contract operations firm that enters into a contractual agreement with the permittee of a land application system to operate the system must fulfill all the requirements of the responsible charge operator and substitute responsible charge operator as designated in section 16.3.1 and section 16.3.2. Proof of such contract shall be submitted to DEQ prior to the contracted operating personnel performing any services at the public wastewater system.

16.3.4 License Requirements Exclusive to Wastewater-Land Application Operators

One type of recycled water system that is not subject to operator licensing requirements are operators that exclusively operate a Class A Effluent Distribution System of a Class A Municipal Reclaimed Wastewater System permitted in accordance with IDAPA 58.01.17. If an operator operates any part of the collection system or treatment system leading up to the Class A Distribution System, then that operator must hold a valid collection or treatment license. It is only if an operator does not operate the collection or treatment system and essentially is an irrigator who distributes the Class A recycled water that this exclusion applies.

The Reuse Permit Program and the wastewater treatment and collection system requirements for licensed operators are administered by DEQ. Individuals who operate land application systems are required to hold two licenses: a wastewater treatment license and a WWLA license. The IBOL administers the testing and licensing of individual wastewater operators.

In Idaho, professional and industrial licensing is conducted by the IBOL through the Board of Drinking Water and Wastewater Professionals. IDAPA 24.05.01 governs the licensing of water operators, backflow assembly testers, and wastewater treatment operators. Separate licenses are available for wastewater treatment operators, wastewater collection system operators, and operators. IDAPA 24.05.01 pertains only to the operator licensing process; all system-related rules are covered in IDAPA 58.01.16.

16.3.5 Licensure of Wastewater Land Application Operators

To become licensed as a WWLA operator, you must complete an approved training class, meet the examination eligibility requirements for the licensure examination, and pass the examination. The WWLA license requires an operator to submit an application to IBOL for an *initial exam* (**not** an application for an endorsement) for the appropriate license type and class.

Applications for examinations must be received at least 30 days prior to the next scheduled meeting of the Idaho Board of Drinking Water and Wastewater Professionals to be reviewed. Examinations will be given only to those applicants who have been approved by the board. A passing examination score is 70% or higher.

To take the examination for licensure as a WWLA operator, you must meet all of the following eligibility requirements:

- Hold a high school diploma or a general educational development equivalent.
- Hold a current wastewater treatment license at a class 1 level or higher.
- Have a minimum of 6 months of hands-on operating experience at a land application system.

The WWLA operator that is a *responsible charge* or *substitute responsible charge operator* must be licensed at the type and class equal to or greater than the classification of the wastewater system.

16.3.6 Responsibilities of Certified Operators

Once licensed, the operator must fulfill the following responsibilities to maintain the license:

- Notify IBOL, in writing, within 30 days of a change of address. Notification can be made via the IBOL website at *http://www.ibol.idaho.gov*.
- Pay an annual renewal fee for each license (a wastewater treatment license and a wastewater land application license are two separate licenses for which a separate annual renewal fee must be paid for each) to IBOL upon receipt of renewal notice.
- Complete 6 hours of approved continuing education training annually. A licensee holding more than one wastewater license is required to meet the annual continuing education requirement for only one license.
- Comply with all terms and conditions of the license and with all statutes and rules regarding the operation of a land application system.
- Comply with all of the requirements of your system's reuse permit.

16.3.7 Disciplinary Actions

Under certain circumstances the board may take disciplinary actions against a licensed operator. The board can revoke, suspend, refuse to issue, refuse to renew, or otherwise limit any licensee for any of the following:

- Procuring a license by knowingly making a false statement, submitting false information, refusing to provide complete information, in response to a question in an application for licensure or through any form of fraud or misrepresentation
- Being convicted of a felony
- Misrepresentation or fraudulent representation in the performance of any duty, conduct or activity regulated under "Drinking Water and Wastewater Professionals Licensing Act" (Idaho Code §54-24).
- Violating the provisions of Idaho Code §54-24, or any rules of the board, or any code of conduct or ethical standards adopted by the board.
- Being negligent or incompetent.
- Failing to provide appropriate and personal supervision, if acting as the designated responsible charge operator, to any person gaining experience under the provisions of Idaho Code §54-24.

Disciplinary actions through IDAPA 24.05.01 and in Idaho Code §54-24 may include the following:

- Civil fines not to exceed $1,000 for each violation
- Imprisonment
- Paying costs and fees incurred by the board in investigating or prosecuting the licensee for violating Idaho Code §54-24

16.4 Other Regulations

In addition to state and federal regulations, local regulations may apply to land application systems. Generally, local regulations deal with the zoning or location of land application systems rather than the actual operation of these facilities.

It is beyond the scope of this manual to review local regulations and the legal issues pertinent to them. Permittees and WWLA operators of land application systems should research the pertinent local regulations to ensure they are in compliance. Information on such regulations should be available from the county planning and zoning office or the local health district.

Permittees are also subject to *third-party lawsuits*. A third-party lawsuit is brought by a person who is not responsible for enforcing a regulation. An example could be a lawsuit brought by a neighbor, as opposed to a lawsuit brought by a local, state, or federal government agency. Third-party lawsuits are becoming more commonplace as subdivisions move into rural settings. The best way to avoid such lawsuits is to keep accurate, detailed records and properly operate and maintain the land application system at all times.

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Appendix A. Example Land Application Permits

All current reuse permits issued by DEQ in Idaho can be viewed at *www.deq.idaho.gov/permitting/issued-permits.aspx?records=10&type=Recycled+Water&sort=nameAscending.* Sample reuse permits are provided below.

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Idaho Department of Environmental Quality Reuse Permit M-999-02

(Previous Permit No. LA-000999-01)

The City of Licensure (hereafter "permittee") is hereby authorized to construct, install, and operate a reuse facility in accordance with (1) this permit; (2) IDAPA 58.01.17 "Recycled Water Rules"; (3) an approved plan of operation; and (4) all other applicable federal, state, and local laws, statutes, and rules. This permit is effective from the date of signature and expires on March 31, 2025.

	March 31, 2020
Signature	Date

Makeit Simple

Regional Administrator
Boise Regional Office
Idaho Department of Environmental Quality

Department of Environmental Quality

Boise Regional Office

1445 N. Orchard
Boise, Idaho 83706
(208) 373-0550

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Table of Contents

1. Commonly Used Acronyms and Abbreviations

cwt	a unit of weight measurement equal to 100 pounds
DEQ	Idaho Department of Environmental Quality
DEQ Guidance	DEQ's *Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater*, latest revision
Director	Director of the Idaho Department of Environmental Quality or designee unless otherwise specified
EPA	Environmental Protection Agency
Ei	irrigation efficiency
FM	flow measurement or monitoring description or identifier
GW	prefix for ground water reporting serial number
IDAPA	Idaho Administrative Procedures Act
IDWR	Idaho Department of Water Resources
IWR	irrigation water requirement – any combination of wastewater and supplemental irrigation water applied at rates commensurate to the moisture requirements of the crop, and calculated monthly during the growing season (GS). The equation used to calculate the IWR is: $IWR = P_{def} / E_i$
LG	prefix for lagoon reporting serial number
MG	million gallons
mg/kg	milligram per kilogram
mg/L	milligram per liter
MU	prefix for management unit reporting serial number
NPDES	National Pollution Discharge Elimination System
P_{def}	precipitation deficit - is synonymous with the net irrigation water requirement of the crop and for the purposes of this permit can be found at the following website *http://data.kimberly.uidaho.edu/ETIdaho/*
PO	plan of operation
QAPP	quality assurance project plan
Responsible Official	the facility contact person authorized by the permittee to communicate with DEQ on behalf of the permittee on any matter related to the permit, including without limitation, the authority to communicate with and receive notices from DEQ regarding notices of violation or non-compliance, permit violations, permit enforcement, and permit revocation. The Responsible Official is also responsible for providing written certification of permit application materials, annual report submittals, and other information submitted to DEQ as required by the permit. Any notice to or communication with the Responsible Official is considered a notice to or communication with the permittee. The Responsible Official may designate an Authorized Representative to act as the facility contact person

	for any of the activities or duties related to the permit, except signing and certifying the permit application, which must be done by the Responsible Official. The Authorized Representative shall act as the Responsible Official and shall bind the permittee as described in this definition. Designation of the Authorized Representative shall follow the requirements specified in Section 6.1.3 of the permit.
SU	prefix for soil monitoring unit reporting serial number
SW	prefix for supplemental irrigation water reporting serial number
WW	prefix for wastewater reporting serial number

2. Facility Information

Information Type	Information Specific to This Permit
Type of recycled water	Municipal, Class C facility
Method of treatment	Facultative lagoons, chlorine disinfection, and slow rate recycled water reuse
System Classification	Wastewater Class II facility & Wastewater Land Application
Facility location	0000 W. 999th Avenue, Wastewater, Idaho, 83666, Landapp T20S, R26E, S37
Facility mailing address	P.O. Box 999, Wastewater, Idaho, 83666, Landapp Telephone (208) 555-1212; fax (208) 555-1213
Facility responsible official and authorized representative	Responsible Official: Mayor, (208) 555-1210, (208) 555-1211 Authorized Representative: Iam Incharge, Public Works Director, (208) 555-1212, (208) 555-1213 Notify DEQ within 30 days if there is a change in personnel for any of the above facility contacts. A minor permit modification will be issued by DEQ to confirm the change
Ground Water	Regional Aquifer, 500' depth, SW flow, Public/Domestic and Agriculture Public Water Supply Wells are approximately 3 miles up-gradient of the site
Surface Water	Records River, six miles west of site. Beneficial use: Agriculture

3. Compliance Schedule for Required Activities

Compliance Activity (CA) Number and Completion Due Date	Compliance Activity Description
CA-999-01 Twelve (12) months after permit issuance	**Plan of Operation (PO):** The permittee shall submit for review and approval a PO that reflects current operations and incorporates the requirements of this permit. The PO shall comply with the applicable requirements stated in IDAPA 58.01.17.300.05 and shall address applicable items in the Plan of Operation checklist in the DEQ Guidance. The PO shall include the following site management plans or the permittee may submit the site management plans individually: 1. Buffer zone plan; 2. Cropping plan; 3. Emergency operating plan; 4. Grazing management plan; 5. Irrigation management and scheduling plan; 6. Nuisance and Odor management plan; 7. Runoff management plan; 8. Well location acceptability analysis; 9. Waste solids management plan The PO shall be updated as needed to reflect current operations. The permittee shall notify DEQ of material changes to the PO and copies must be kept on site and made available to DEQ upon request.

<table>
<tr><th>Compliance Activity (CA) Number and Completion Due Date</th><th>Compliance Activity Description</th></tr>
<tr><td>CA-999-02

Twelve (12) months after permit issuance</td><td>Quality Assurance Project Plan (QAPP): The permittee shall prepare and implement a QAPP that incorporates all monitoring and reporting required by this permit. A copy of the QAPP along with written notice that the permittee has implemented the QAPP shall be provided to DEQ.

The QAPP shall be designed to assist in planning for the collection, analysis, and reporting of all monitoring in support of this permit and in explaining data anomalies when they occur. At a minimum, the QAPP must include the following:

1. Details on the number of measurements, number of samples, type of sample containers, preservation of samples, holding times, analytical methods, analytical detection and quantitation limits for each target compound, type and number of quality assurance field samples, precision and accuracy requirements, sample preparation requirements, sample shipping methods, and laboratory data delivery requirements.
2. Maps indicating the location of each monitoring, and sampling point.
3. Qualification and training of personnel.
4. Names, addresses and telephone numbers of the laboratories used by or proposed to be used by the permittee.
5. Example formats and tables that will be used by the permittee to summarize and present all data in the Annual Report.

The format and the content of the QAPP should adhere to the recommendations and references in the Quality Assurance and Data Processing sections of the DEQ Guidance.

The permittee shall amend the QAPP whenever there is a modification in sample collection, sample analysis, or other procedure addressed by the QAPP. The permittee shall notify DEQ of material changes to the QAPP and copies must be kept on site and made available to DEQ upon request.</td></tr>
<tr><td>CA-999-03

As specified</td><td>Seepage Testing: The following table shows the date by which the permittee shall complete seepage testing on the specified lagoons:
<table><tr><td>Lagoon:</td><td>Seepage Test Due Date:</td></tr><tr><td>Treatment Lagoon #1</td><td>July/2024</td></tr><tr><td>Treatment Lagoon #2</td><td>July/2024</td></tr><tr><td>Winter Storage Lagoon</td><td>July/2024</td></tr></table>
Submit to DEQ for review and approval a proposed schedule and procedure for performing the required seepage tests at least 42 days prior to the planned seepage test.

The seepage test procedures shall be sealed by the Idaho licensed professional engineer or professional geologist in responsible charge for the test.

Seepage tests shall be completed in accordance with the procedures approved by DEQ. The seepage test report shall be sealed by the person in responsible charge and submitted within 90 days after completion of the seepage test.</td></tr>
</table>

Compliance Activity (CA) Number and Completion Due Date	Compliance Activity Description
CA-999-04 One (1) year prior to the expiration date of this permit	**Pre-Application Workshop**: If the permittee intends to continue operating the reuse facility beyond the expiration date of this permit, the permittee shall contact DEQ and schedule a pre-application workshop to discuss the compliance status of the facility and the content required for the reuse permit application package.
CA-999-05 180 days prior to the expiration date of this permit	**Renewal Permit Application:** The permittee shall submit to DEQ a complete permit renewal application package, which fulfills the requirements specified at the pre-application workshop identified in CA-999-04.

4. Permit Limits and Conditions

4.1 Hydraulic Management Unit Descriptions

Serial Number	Description	Irrigation System Type and Irrigation Efficiency (E_i)	Maximum Acres[a] Allowed
MU-999-01	West Field	Solid Set: (E_i = 0.75)	75
MU-999-02	Pivot 1	Pivot: (E_i = 0.85)	125
		Total acreage	200

a. Maximum acres represent the total permitted acreage of the MU as provided by the permittee. If the permittee uses less acreage in any season or year, then loading rates shall be presented and compliance shall be determined based on the actual acreage utilized during each season or year.

4.2 Hydraulic Loading Limits

Serial Number	Growing Season Hydraulic Loading	Nongrowing Season Maximum Hydraulic Loading
MU-999-01 MU-999-02	Substantially at the irrigation water requirement (IWR)[a]	Not allowed

a. For compliance purposes, the source of P_{def} data used to calculate the IWR shall be specified in the PO.

4.3 Constituent Loading Limits

Serial Number	Constituent Loading (from all sources)			
	Nitrogen (lb/acre)	Salt (NVDS) (lb/acre)	COD growing season (lb/acre-day)[a]	COD nongrowing season (lb/acre-day)[a]
MU-999-01 MU-999-02	150% of typical crop uptake[b]	None	50	None

a. COD limits are expressed in pounds per acre per day (lb/acre-day) based on a seasonal average.
b. Typical crop uptake is the median constituent crop uptake from the 3 most recent years the crop has been grown. For crops having less than 3 years of on-site crop uptake data, other crop yield data or nutrient content values may only be used if approved in writing by DEQ in advance of use. If written approval is not provided by DEQ, compliance with the 150% nitrogen loading limit shall be determined by comparing the current year nitrogen loading to the current year nitrogen uptake.

4.4 Management Unit Buffer Zones

Serial Number	Buffer Distances (in feet) from Management Units					
	Public Water Supplies	Private Water Supplies	Inhabited Dwellings	Permanent and Intermittent Surface Water	Irrigation Ditches and Canals	Areas Accessible to the Public
MU-999-01 MU-999-02	1,000	500	300	100	50	50

4.5 Other Permit Limits and Conditions

Category	Permit Limits and Conditions
Growing season	April 1 through October 31 (214 days)
Nongrowing season	November 1 through March 31 (151 days)
Reporting year for annual loading rates	November 1 through October 31
Operator certification and endorsement	The wastewater treatment facility and reuse systems shall be operated by personnel certified and licensed in the state of Idaho wastewater operator training program at the operator class level specified in IDAPA 58.01.16.203 and properly trained to operate and maintain the system.
Disinfection limits in recycled water	Class C: The median number of total coliform organisms does not exceed 23 total coliform organisms/100 mL, as determined from the bacteriological results of the last 5 days for which analyses have been completed. No sample shall exceed 230 total coliform organisms/100 mL in any confirmed sample.
Crop or vegetation restrictions	Restricted to crops not grown for direct human consumption (crops must be processed prior to human consumption).
Grazing	Prior to grazing, the permittee shall submit a grazing management plan to DEQ and receive written approval from DEQ.
Posting	Signs shall read “Warning: Recycled Water—Do Not Drink,” or equivalent signage both in English and Spanish. Signs to be posted every 500 feet and at each corner of the outer perimeter of the irrigated site. Signs are required where management unit border areas are accessible to the public.
Fencing	Three-wire pasture fencing or equivalent is required.

Category	Permit Limits and Conditions
Construction Plans	Pursuant to Idaho Code §39-118, IDAPA 58.01.16, and IDAPA 58.01.17, detailed plans and specifications shall be submitted to DEQ for review and approval prior to construction, modification, or expansion of any wastewater treatment, storage, conveyance structures, or reuse facility. Inspection requirements shall be satisfied and within 30 days of completion of construction and the permittee shall submit as-built plans or a letter from an Idaho Professional Engineer certifying the facilities or structures were constructed in substantial accordance with the approved plans and specifications.
Backflow prevention and testing requirements	Backflow prevention is required to protect surface water and ground water from an unauthorized discharge of recycled water or wastewater. Refer to section 9.1.1 of this permit.
Records retention requirements	Keep records generated to meet the requirements of this permit for the duration of the permit, including administrative extensions, plus 2 years.

5. Monitoring Requirements

5.1 Recycled Water and Supplemental Irrigation Water Sampling and Analyses

5.1.1 Constituent Monitoring

Monitoring Point Serial Number and Location	Sample Description	Sample Type and Frequency	Constituents (Units in mg/L Unless Otherwise Specified)
WW-999-01 Recycled water from lagoons at pumping station sample port	Wastewater quality to all management units (during periods of recycled water land application)	Grab/monthly	- chemical oxygen demand - total Kjeldahl nitrogen - nitrate + nitrite nitrogen - total phosphorus - pH - total dissolved solids (TDS) - volatile dissolved solids (VDS) - sulfate
		Grab/weekly	- total coliform organisms/100 mL - chlorine residual
SW-999-01 Irrigation well sample port	Supplemental irrigation water quality to all management units	Grab/annually: May	- nitrate-nitrogen - total phosphorus - total dissolved solids (TDS) - volatile dissolved solids (VDS) - pH - sulfate

5.1.2 Management Unit and Other Flow Monitoring

Management Unit or Flow Measurement Serial Number and Location	Sample Description	Sample Type and Frequency	Measured Parameter, each MU
MU-999-01 MU-999-02	Recycled water flow from LG-999-03	- Daily meter reading; - Monthly compilation of data; (during periods of reuse water land application)	- Volume (MG/month) - Application depth (inches/month)
MU-999-01 MU-999-02	Supplemental irrigation water from irrigation well #1	- Daily meter reading; - Monthly compilation of data; (during periods of supplemental irrigation)	- Volume (MG/month) - Application depth (inches/month)
FM-999-01	Wastewater influent volume	- Daily meter reading; - Monthly compilation of data	- Volume (MG/month) - Volume (MG/year)

5.2 Ground Water Monitoring

5.2.1 Ground Water Monitoring Point Descriptions

Monitoring Point Serial Number	Common Designation	Well Type	Gradient Location
GW-999-01	MW-1	Monitoring well	Up-gradient
GW-999-02	MW-2	Monitoring well	Down-gradient
GW-999-03	MW-3	Monitoring well	Down-gradient
GW-999-04	Private Well[a]	Domestic well	Down-gradient

a. Obtain owner permission prior to sampling. Written documentation shall be provided if owner declines to have the well sampled.

5.2.2 Ground Water Monitoring, Sampling, and Analyses

Monitoring Point Serial Number	Sampling Point Description	Sample Type and Frequency	Constituents (Units in mg/L Unless Otherwise Specified)
GW-999-01 GW-999-02 GW-999-03	Monitoring wells	Unfiltered grab sample / twice annually: April, October	- water table elevation (ft) - water table depth (ft) - nitrate-nitrogen, as N - chloride - total coliform/100 mL
GW-999-04	Domestic well (monitored contingent on owner's permission)	Unfiltered grab sample/October of 2020 and 2024	- sodium - potassium - calcium - magnesium - sulfate, as S - chloride - alkalinity (as $CaCO_3$)

5.3 Soil Monitoring

5.3.1 Soil Monitoring Unit Descriptions

Monitoring Point Serial Number	Description	Associated Management Unit
SU-999-01	West Field	MU-999-01
SU-999-02	Pivot 1	MU-999-02

5.3.2 Soil Monitoring, Sampling, and Analyses

Monitoring Point Serial Number	Sample Type	Sample Frequency	Constituents (Units in mg/kg Soil Unless Otherwise Specified)
SU-999-01 SU-999-02	Composite samples[a]	Annually: April (during periods of reuse water land application)	- electrical conductivity (umhos/cm in saturated paste extract) - nitrate-nitrogen - ammonium-nitrogen - plant available phosphorus (Olsen method – soils with pH 6.5 or greater, Bray method – soils with pH less than 6.5) - pH (standard units)

Monitoring Point Serial Number	Sample Type	Sample Frequency	Constituents (Units in mg/kg Soil Unless Otherwise Specified)

a. The number of sample locations specified in the PO or QAPP for each SU shall be sampled. At each location, samples shall be obtained from three depths: 0–12 inches; 12–24 inches; and 24–36 inches or refusal. The samples obtained from each depth shall be composited by depth to yield three composite samples for each soil monitoring unit; one composite sample for each depth.

5.4 Plant Tissue Monitoring

5.4.1 Crop Harvest Monitoring

Associated Hydraulic Management Units	Sample Type	Sample Frequency	Parameters[a]
MU-999-01 MU-999-02	Harvested portion, each crop, each MU	Each harvest	- Crop Type - Harvest Date - Sample Collection Date - Harvest acreage (acres) - As-harvested (‘wet’) Yield in customary harvested units (tons, bushels, cwt, etc.) - As-harvested (field) moisture content (%) - Dry Yield (lbs)

a. Documentation of reported yields shall be provided for each harvest from each MU.

5.4.2 Plant Tissue Monitoring

Associated Hydraulic Management Units	Sample Type	Sample Frequency	Parameters[a]
MU-999-01 MU-999-02	Harvested portion, each crop, each harvest	Each harvest	- moisture content (%) - Total Kjeldahl nitrogen (%) - Nitrate nitrogen, as N (ppm) - Phosphorus as P (ppm) - ash (%)

a. Report dry-basis results for all parameters except lab moisture content.

5.5 Lagoon Information

Serial number	Description	Surface Area (acres)	Maximum Operating Volume (MG)	Liner Type
LG-999-01	Treatment Lagoon #1	0.5	1	HDPE
LG-999-02	Treatment Lagoon #2	0.5	1	HDPE
LG-999-03	Winter Storage Lagoon	3	10	HDPE

6. Reporting Requirements

6.1 Annual Report Requirements

The permittee shall submit to DEQ an Annual Report prepared by a competent environmental professional covering the previous reporting year.

6.1.1 Due Date

The Annual Report is due no later than January 31 of each year, which shall cover the previous reporting year.

6.1.2 Required Contents

The Annual Report shall include the following:

1. A brief interpretive discussion of all required monitoring data. The discussion shall address data quality objectives, validation, and verification; permit compliance; and reuse facility environmental impacts. The reporting year for this permit is specified in section 4.5.
2. Results of the required monitoring as described in section 5 of this permit. If the permittee monitors any parameter for compliance purposes more frequently than required by this permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the Annual Report. The report shall present all monitoring data in organized data summary tables to expedite review.
3. Status of all work described in section 3 of this permit.
4. Results of all backflow testing, repairs, and replacements required by Section 9.1.1 of this permit.
5. Discussion of major maintenance activities such as major equipment replacement, liner maintenance, and wastewater treatment and reuse facility maintenance.
6. A summary of all noncompliance events that occurred during the reporting year. Examples of noncompliance events that must be discussed include, but are not limited to: complaints, missed monitoring events, incorrect monitoring dates or frequencies, dry monitoring wells, uncontained spills causing runoff, construction without DEQ engineering plan approval, construction without engineering inspection, and reporting incorrect acreage.
7. Submittal of the calculations and observations for hydraulic management units specified in the table below.
8. All laboratory analytical reports, chain of custody forms, and crop yield documentation.
9. The parameters in the following table:

Monitoring Point Serial Number	Parameter (Calculate for each MU)	Units
MU-999-01 MU-999-02	Recycled water loading rate	Million gallons/month Inches/month
	Irrigation water loading rate	Million gallons/month Inches/month
	Irrigation water requirement (IWR) for each crop	Inches/month Inches/GS
	COD loading rate: growing season seasonal average	Pounds/acre-day
	Recycled water nitrogen, phosphorus and NVDS loading rates	Pounds/acre-year
	Supplemental Irrigation water nitrogen, phosphorus and NVDS loading rates	Pounds/acre-year
	Fertilizer nitrogen and phosphorus application rates, reported as elemental N and P	Pounds/acre-year
	Waste solids nitrogen and phosphorus application rates	Pounds/acre-year
	Crop Harvest and Yield Report each harvest and the annual totals for each MU.	Crop Types Harvested Total Harvested Area(acres/yr) Total 'wet' yield (lb/yr, lb/acre-yr) Total 'dry' yield (lb/yr, lb/acre-yr)
	Crop nitrogen, phosphorus, and ash removal rates (dry-basis) Report each harvest and the annual totals for each MU.	Pounds-N/acre-year Pounds-P/acre-year Pounds Ash/acre-year
Other Reporting Requirements: 1. Visual observation of field conditions: areas of ponding, ice, and unusual conditions.		

6.1.3 Submittal

All applications, annual reports, or information submitted to DEQ as required by this permit shall be signed and certified as follows:

1. Permit applications shall be signed by the Responsible Official as follows:
    a. For a corporation: by a responsible corporate officer;
    b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively;
    c. For a municipality, state, federal, Indian tribe, or other public agency: by either the principal executive officer or ranking elected official.

2. Annual reports and other information requested by DEQ shall be signed by the Responsible Official or by a duly Authorized Representative of that person. A person is a duly Authorized Representative only if:
    a. The authorization is made in writing by the responsible official;
    b. The authorization specifies either an individual or position having responsibility for the overall operation or the regulated facility, such as the position of plant manager, superintendent, position of equivalent responsibility, or an individual having overall responsibility for environmental matters for the company; and
    c. The written authorization is submitted to DEQ.

Submit the annual report to the following DEQ regional office at this address:

Engineering Manager
Idaho Department of Environmental Quality
Boise Regional Office
1445 N. Orchard
Boise, ID 83706

The annual report shall include the following certification statement and be signed, dated, and certified by the permittee's Responsible Official or Authorized Representative:

> "*I certify that the information in this submittal was prepared in conformance with the Quality Assurance Project Plan required by permit M-999-02, and is to the best of my knowledge, true, accurate and complete and I acknowledge that knowing submission of false or incomplete information may result in permit revocation as provided for in IDAPA 58.01.17.920.01 or other enforcement action as provided for under Idaho law.*"

6.2 Emergency and Noncompliance Reporting

Report noncompliance incidents to DEQ's regional office at (208) 373-0550 or 1-888-800-3480.

In case of emergencies, call the emergency 24-hour number at 1-800-632-8000 and DEQ's regional office.

See Section 8, "Standard Permit Conditions," **and IDAPA 58.01.17.500.06 for reporting requirements for facilities.**

All instances of unpermitted discharges of wastewater to Surface Waters of the United States shall also be reported to the Environmental Protection Agency by telephone within 24 hours from the time the permittee becomes aware of the discharge and in writing within five days at this address:

NPDES/Stormwater Coordinator, USEPA Idaho Operations Office

950 W. Bannock, Suite 900

Boise, ID 83702

208-378-5746 / 208-378-5744 and EPA Hot Line (206) 553-1846

7. Reserved

8. Standard Permit Conditions

The following standard permit conditions are included as terms of this permit as required by the "Recycled Water Rules," (**IDAPA 58.01.17.500).**

500. STANDARD PERMIT CONDITIONS.

The following conditions shall apply to and be included in all permits. (4-1-88)

01. Compliance Required. The permittee shall comply with all conditions of the permit . (4-1-88)

02. Renewal Responsibilities. If the permittee intends to continue operation of the permitted facility after the expiration of an existing permit, the permittee shall apply for a new permit in accordance with these rules. (4-1-88)

03. Operation of Facilities. The permittee shall at all times properly maintain and operate all structures, systems, and equipment for treatment, control and monitoring, which are installed or used by the permittee to achieve compliance with the permit or these rules. (4-1-88)

04. Provide Information. The permittee shall furnish to the Director within a reasonable time, any information including copies of records, which may be requested by the Director to determine whether cause exists for modifying, revoking, re-issuing, or terminating the permit, or to determine compliance with the permit or these rules. (4-1-88)

05. Entry and Access. The permittee shall allow the Director, consistent with Title 39, Chapter 1, Idaho Code, to: (4-1-88)

a. Enter the permitted facility. (4-1-88)

b. Inspect any records that must be kept under the conditions of the permit. (4-1-88)

c. Inspect any facility, equipment, practice, or operation permitted or required by the permit. (4-1-88)

d. Sample or monitor for the purpose of assuring permit compliance, any substance or any parameter at the facility. (4-1-88)

06. **Reporting**. The permittee shall report to the Director under the circumstances and in the manner specified in this section: (4-1-88)

a. In writing at least thirty (30) days before any planned physical alteration or addition to the permitted facility or activity if that alteration or addition would result in any significant change in information that was submitted during the permit application process. When the alteration or addition results in a need for a major modification, such alteration or addition shall not be made prior to Department approval issued in accordance with these rules. (4-7-11)

b. In writing thirty (30) days before any anticipated change which would result in noncompliance with any permit condition or these rules. (4-1-88)

c. Orally within twenty-four (24) hours from the time the permittee became aware of any noncompliance which may endanger the public health or the environment at telephone numbers provided in the permit by the Director.(4-1-88)

d. In writing as soon as possible but within five (5) days of the date the permittee knows or should know of any noncompliance unless extended by the Department. This report shall contain: (4-1-88)

i. A description of the noncompliance and its cause; (4-1-88)

ii. The period of noncompliance including to the extent possible, times and dates and, if the noncompliance has not been corrected, the anticipated length of time it is expected to continue; and (4-7-11)

iii. Steps taken or planned, including timelines, to reduce or eliminate the continuance or reoccurrence of the noncompliance. (4-7-11)

e. In writing as soon as possible after the permittee becomes aware of relevant facts not submitted or incorrect information submitted, in a permit application or any report to the Director. Those facts or the correct information shall be included as a part of this report. (4-1-88)

07. **Minimize Impacts**. The permittee shall take all necessary actions to eliminate and correct any adverse impact on the public health or the environment resulting from permit noncompliance. (4-1-88)

08. **Compliance with "Ground Water Quality Rule."** Permits issued pursuant to these rules shall require compliance with IDAPA 58.01.11, "Ground Water Quality Rule." (4-7-11)

9. General Permit Conditions

The following general permit conditions are based on the cited rules at the time of issuance and are enforceable as part of this permit. Note that the rules cited in this section, and elsewhere in this permit, are supplemented by the rules themselves. Rules applicable to your facility are enforceable whether or not they appear in this permit.

9.1 Operations

9.1.1 Backflow Prevention

Reuse facilities with existing or planned cross-connections or interconnections between the recycled water system and any water supply (potable or nonpotable), or surface water, shall have backflow prevention assemblies, devices, or methods as required by the applicable rule or as specified in this permit and approved by DEQ.

For public water systems, backflow assemblies shall meet the requirements of IDAPA 58.01.08.543. Assemblies shall be adequately maintained and shall be tested annually by a certified backflow assembly tester, and repaired or replaced as necessary to maintain operational status.

For domestic water supply wells, backflow prevention devices shall meet the requirements of IDAPA 07.02.04 and shall be adequately operated and maintained.

Irrigation water supply wells shall meet the requirements of IDAPA 37.03.09.36 for preventing any waste or contamination of the ground water resource. Backflow prevention assemblies or devices used to protect the ground water shall be adequately operated and maintained.

Discharge of recycled water to surface water is regulated by the EPA NPDES program. An NPDES permit is required for any discharge to surface water and backflow prevention shall be implemented to prevent any unauthorized discharge. Backflow prevention assemblies or devices used to protect the ground water shall be adequately operated and maintained.

Records of all testable backflow assembly test results, repairs, and replacements shall be kept at the reuse facility along with other operational records, and shall be discussed in the Annual Report and made available for inspection by DEQ. Other approved means of backflow prevention, such as siphons and air-gap structures that cannot be tested, shall be maintained in operable order.

9.1.2 Restricted to Premises

Wastewaters or recharge waters applied to the land surface must be restricted to the premises of the application site. Wastewater discharges to surface water that require a permit under the Clean Water Act must be authorized by the United States Environmental Protection Agency (IDAPA 58.01.16.600.02).

9.1.3 Health Hazards, Nuisances, and Odors Prohibited

Health hazards, nuisances, and odors are prohibited as follows:

- Wastewater must not create a public health hazard or nuisance condition (IDAPA 58.01.16.600.03).
- No person shall allow, suffer, cause or permit the emission of odorous gases, liquids, or solids into the atmosphere in such quantities as to cause air pollution (IDAPA 58.01.01.776.01).
- Air Pollution. The presence in the outdoor atmosphere of any air pollutant or combination thereof in such quantity of such nature and duration and under such conditions as would be injurious to human health or welfare, to animal or plant life, or to property, or to interfere unreasonably with the enjoyment of life or property (IDAPA 58.01.01.006.06).

9.1.4 Solids Management

Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge. When treated and processed, sewage sludge becomes biosolids which can be safely recycled and applied as fertilizer to sustainably improve and maintain productive soils and stimulate plant growth.

Biosolids generated from sewage sludge are regulated by EPA under 40 CFR Part 503 and require a DEQ approved sludge disposal plan as outlined in IDAPA 58.01.16.650. Contact DEQ prior to application of biosolids at any permitted reuse facility.

Sludge is the semi-liquid mass produced and removed by wastewater treatment processes. This does not include grit, garbage, and large solids.

Sludge is generated by wastewater treatment processes at municipal and industrial facilities.

Solid Waste is any garbage or refuse, sludge from a waste water treatment plant, water supply treatment plant, or air pollution control facility and other discarded material including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved material in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended or source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended.

Solid waste does not include inert wastes, manures and crop residues ultimately returned to the soils at agronomic rates, and any agricultural solid waste which is managed and regulated pursuant to rules adopted by the Idaho Department of Agriculture. DEQ reserves the right to use existing authorities to regulate agricultural waste that impacts human health or the environment.

Solid waste is regulated under “Solid Waste Management Rules”, IDAPA 58.01.06. Wastes otherwise regulated by DEQ (i.e. this permit) are not regulated under 58.01.06.

Waste Solids include sludge and wastes otherwise regulated by DEQ in accordance with IDAPA 58.01.06.001.03.a.xii. Waste solids may include vegetative waste, silt and mud containing organic matter, and other non-inert solid wastes.

Inert wastes are defined as non-combustible, nonhazardous, and non-putrescible solids wastes that are likely to retain their physical and chemical structure and have a de minimis potential to generate leachate under expected conditions of disposal, which includes resistance to biological attack.

Waste solids require a DEQ approved sludge disposal plan as outlined in IDAPA 58.01.16.650.

9.1.5 Temporary Cessation of Operations and Closure (IDAPA 58.01.17.801)

Temporary cessation of operations and closure must be addressed as follows:

01. Temporary Cessation. A permittee shall implement any applicable conditions specified in the permit for temporary cessation of operations. When the permit does not specify applicable temporary cessation conditions, the permittee shall notify the Director prior to a temporary cessation of operations at the facility greater than sixty (60) days in duration and any cessation not for regular maintenance or repair. Cessation of operations necessary for regular maintenance or repair of a duration of sixty (60) days or less are not required to notify the Department under this section. All notifications required under this section shall include a proposed temporary cessation plan that will ensure the cessation of operations will not pose a threat to human health or the environment. (4-7-11)

02. Closure. A closure plan shall be required when a facility is closed voluntarily and when a permit is revoked or expires. A permittee shall implement any applicable conditions specified in the permit for closure of the facility. Unless otherwise directed by the terms of the permit or by the Director, the permittee shall submit a closure plan to the Director for approval at least ninety (90) days prior to ceasing operations. The closure plan shall ensure that the closed facility will not pose a threat to human health and the environment. Closure plan approval may be conditioned upon a permittee's agreement to complete such site investigations, monitoring, and any necessary remediation activities that may be required. (4-7-11)

9.1.6 Plan of Operation (IDAPA 58.01.17.300.05)

The PO must comply with the following:

05. Reuse Facility Operation and Maintenance Manual or Plan of Operations. A facility's operation and maintenance manual must contain all system components relating to the reuse facility in order to comply with IDAPA 58.01.16 "Wastewater Rules," Section 425. Manuals and manual amendments are subject to the review and approval provision therein. In addition to the content required by IDAPA 58.01.16.425, manuals for reuse facilities shall include, if applicable: operation and management responsibility, permits and standards, general plant description, operation and control of unit operations, land application site maps, wastewater characterization, cropping plan, hydraulic loading rate, constituent loading rates, compliance activities, seepage rate testing, site management plans, monitoring, site operations and maintenance, solids handling and processing, laboratory testing, general maintenance, records and reports, store room and inventory, personnel, an emergency operating plan, and any other information required by the Department. (4-7-11)

9.1.7 Seepage Testing Requirements (IDAPA 58.01.16.493.02.c)

Subsequent Tests. All lagoons covered under these rules must be seepage tested by an Idaho licensed professional engineer, an Idaho licensed professional geologist, or by individuals under their supervision every ten (10) years after the initial testing. (5-8-09)

9.1.8 Ground Water Quality (IDAPA 58.01.11)

The permittee shall comply with the requirements of "Ground Water Quality Rule" (IDAPA 58.01.11).

9.2 Administrative

Requirements for administration of the permit are defined as follows.

9.2.1 Permit Modification (IDAPA 58.01.17.700)

01. Modification of Permits. A permit modification may be initiated by the receipt of a request for modification from the permittee, or may be initiated by the Department if one (1) of more of the following causes for modification exist: (4-7-11)

a. Alterations. There are material and substantial alterations or additions to the permitted facility or activity which occurred after permit issuance which justify the application of permit conditions that are different or absent in the existing permit. (4-7-11)

b. New standards or regulations. The standards or regulations on which the permit was based have been changed by promulgation of amended standards or regulations or by judicial decision after the permit was issued. (4-7-11)

c. Compliance schedules. The Department determines good cause exists for modification of a compliance schedule or terms and conditions of a permit. (4-7-11)

d. Non-limited pollutants. When the level of discharge of any pollutant which is not limited in the permit exceeds the level which may cause an adverse impact to surface or ground waters. (4-7-11)

e. To correct technical mistakes, such as errors in calculation, or mistaken interpretations of law made in determining permit conditions. (4-7-11)

f. When a treatment technology proposed, installed, and properly operated and maintained by the permittee fails to achieve the requirements of the permit. (4-7-11)

9.2.2 Permit Transferable (IDAPA 58.01.17.800)

01. General. A permit may be transferred only upon approval of the Department. No transfer is required for a corporate name change as long as the secretary of state can verify that a change in name alone has occurred. An attempted transfer is not effective for any purpose until approved in writing by the Department. (4-7-11)

9.2.3 Permit Revocation (IDAPA 58.01.17.920)

01. Conditions for Revocation. The Director may revoke a permit if the permittee violates any permit condition or these rules, or the Director becomes aware of any omission or misrepresentation of condition or information relied upon when issuing the permit. (4-7-11)

02. Notice of Revocation. Except in cases of emergency, the Director shall issue a written notice of intent to revoke to the permittee prior to final revocation. Revocation shall become final within thirty-five (35) days of receipt of the notice by the permittee, unless within that time the permittee requests an administrative hearing in writing. The hearing shall be conducted in accordance with IDAPA 58.01.23, Rules of Administrative Procedure Before the Board of Environmental Quality." (5-3-03)

03. Emergency Action. If the Director finds the public health, safety or welfare requires emergency action, the Director shall incorporate findings in support of such action in a written notice of emergency revocation issued to the permittee. Emergency revocation shall be effective upon receipt by the permittee. Thereafter, if requested by the permittee in writing, the Director shall provide the permittee a revocation hearing and prior notice thereof. Such hearings shall be conducted in accordance with IDAPA 58.01.23, Rules of Administrative Procedure Before the Board of Environmental Quality." (3-15-02)

04. Revocation and Closure. A permittee shall perform the closure requirements in a permit, the closure requirements of these rules, and complete all closure plan activities notwithstanding the revocation of the permit. (4-7-11)

9.2.4 Violations (IDAPA 58.01.17.930)

Any person violating any provision of these rules or any permit or order issued thereunder shall be liable for a civil penalty not to exceed ten thousand dollars ($10,000) or one thousand dollars ($1,000) for each day of a continuing violation, whichever is greater. In addition, pursuant to Title 39, Chapter 1, Idaho Code, any willful or negligent violation may constitute a misdemeanor. (4-1-88)

9.2.5 Severability

The provisions of this permit are severable, and if a provision or its application is declared invalid or unenforceable for any reason, that declaration will not affect the validity or enforceability of the remaining provisions.

9.3 Other Applicable Laws

DEQ may refer enforcement of the following provisions to the state agency authorized to enforce that rule. The permittee shall comply with all applicable provisions identified in this section, as well as all other applicable federal, state, and local laws, statutes, and rules.

9.3.1 Owner Responsibilities for Well Use and Maintenance

9.3.2 Well Use

The well owner must not operate any well in a manner that causes waste or contamination of the ground water resource. Failure to operate, maintain, knowingly allow the construction of any well in a manner that violates these rules, or failure to repair or properly decommission (abandon) any well as herein required will subject the well owner to civil penalties as provided by statute. See IDAPA 37.03.09.036.01 and consult the Idaho Department of Water Resources (IDWR) for more information.

9.3.3 Well Maintenance

The well owner must maintain the well to prevent waste or contamination of ground waters through leaky casings, pipes, fittings, valves, pumps, seals, or through leakage around the outside of the casings, whether the leakage is above or below the land surface. Any person owning or controlling a noncompliant well must have the well repaired by a licensed well driller under a permit issued by the IDWR director in accordance with the applicable rules. See IDAPA 37.03.09.036.02 and consult IDWR for more information.

9.3.4 Wells Posing a Threat to Human Health and Safety or Causing Contamination of the Ground Water Resource

The well owner must have any well shown to pose a threat to human health and safety or cause contamination of the ground water resource immediately repaired or decommissioned (abandoned) by a licensed well driller under a permit issued by the IDWR director in accordance with the applicable rules. See IDAPA 37.03.09.036.06 and consult the IDWR for more information.

9.4 Site Maps

9.5 Regional Map

This map is designed to show the reuse site in relation to major surrounding features such as cities, water bodies, highways and roads, county boundaries, state boundaries, etc…

9.6 Facility Map(s)

This map will contain at a minimum, hydraulic management units (boundaries and size in acres), ground water monitoring wells, and lagoons.

Other features that may be included are public water supply(s), private wells, surface waters, public roads, and waste solids storage or application areas.

Note:

Other maps and figures can be included if necessary to interpret the reuse permit:

- Soil management unit map when soil management units do not coincide with hydraulic management unit boundaries (including NRCS soil maps)
- Ground water flow contour maps
- Location of other environmental monitoring points (influent wastewater, surface water, specific flow measurement locations, etc.

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Idaho Department of Environmental Quality
Reuse Permit
I-998-02

(Previous Permit No. LA-000998-01)

Potato World (hereafter "permittee") is hereby authorized to construct, install, and operate a reuse facility in accordance with (1) this permit; (2) IDAPA 58.01.17 "Recycled Water Rules"; (3) an approved plan of operation; and (4) all other applicable federal, state, and local laws, statutes, and rules. This permit is effective from the date of signature and expires on March 31, 2024.

March 31, 2019

Signature ______________________ Date

Makeit Simple

Regional Administrator
Boise Regional Office
Idaho Department of Environmental Quality

Department of Environmental Quality

Boise Regional Office

1445 N. Orchard
Boise, Idaho 83706
(208) 373-0550

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Table of Contents

1. Commonly Used Acronyms and Abbreviations

cwt	a unit of weight measurement equal to 100 pounds
DEQ	Idaho Department of Environmental Quality
DEQ Guidance	DEQ Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater, latest revision
Director	Director of the Idaho Department of Environmental Quality or designee unless otherwise specified
EPA	Environmental Protection Agency
Ei	irrigation efficiency
FM	flow measurement or monitoring description or identifier
GW	prefix for ground water reporting serial number
IDAPA	Idaho Administrative Procedures Act
IDWR	Idaho Department of Water Resources
IWR	irrigation water requirement – any combination of wastewater and supplemental irrigation water applied at rates commensurate to the moisture requirements of the crop, and calculated monthly during the growing season (GS). The equation used to calculate the IWR is: $IWR = P_{def} / E_i$
LG	prefix for lagoon reporting serial number
MG	million gallons
mg/kg	milligram per kilogram
mg/L	milligram per liter
MU	prefix for management unit reporting serial number
NPDES	National Pollution Discharge Elimination System
P_{def}	precipitation deficit - is synonymous with the net irrigation water requirement of the crop and for the purposes of this permit can be found at the following website *http://data.kimberly.uidaho.edu/ETIdaho/*
PO	plan of operation
QAPP	quality assurance project plan
Responsible Official	the facility contact person authorized by the permittee to communicate with DEQ on behalf of the permittee on any matter related to the permit, including without limitation, the authority to communicate with and receive notices from DEQ regarding notices of violation or non-compliance, permit violations, permit enforcement, and permit revocation. The Responsible Official is also responsible for providing written certification of permit application materials, annual report submittals, and other information submitted to DEQ as required by the permit. Any notice to or communication with the Responsible Official is considered a notice to or communication with the permittee. The Responsible Official may designate an Authorized Representative to act as the facility contact person

	for any of the activities or duties related to the permit, except signing and certifying the permit application, which must be done by the Responsible Official. The Authorized Representative shall act as the Responsible Official and shall bind the permittee as described in this definition. Designation of the Authorized Representative shall follow the requirements specified in Section 6.1.3 of the permit.
SU	prefix for soil monitoring unit reporting serial number
SW	prefix for supplemental irrigation water reporting serial number
WW	prefix for wastewater reporting serial number

2. Facility Information

Information Type	Information Specific to This Permit
Type of recycled water	Industrial, Potato Processing
Method of treatment	Primary clarification and slow rate land application
Facility location	111 E. Spoil Street, Spud City, Idaho, 83665, Fryland T19S, R25E, S38
Facility mailing address	P.O. Box 998, Spud City, Idaho, 83665, Fryland Telephone (208) 999-1212; fax (208) 999-1213
Facility responsible official and authorized representative	Responsible Official: Plant Manager, (208) 999-1210, (208) 999-1211 Authorized Representative: Iam King, (208) 999-1212, (208) 999-1213 Notify DEQ within 30 days if there is a change in personnel for any of the above facility contacts. A minor permit modification will be issued by DEQ to confirm the change
Ground Water	Regional Aquifer, 300’ depth, NW flow, Public/Domestic and Agriculture Public Water Supply Wells are approximately 2 miles up-gradient of the site
Surface Water	Operation Canal, one mile east of site. Beneficial use: Agriculture

3. Compliance Schedule for Required Activities

Compliance Activity (CA) Number and Completion Due Date	Compliance Activity Description
CA-998-01 Twelve (12) months after permit issuance	**Plan of Operation (PO):** The permittee shall submit for review and approval a PO that reflects current operations and incorporates the requirements of this permit. The PO shall comply with the applicable requirements stated in IDAPA 58.01.17.300.05 and shall address applicable items in the Plan of Operation checklist in the DEQ Guidance. The PO shall include the following site management plans or the permittee may submit the site management plans individually: 1. Buffer zone plan; 2. Cropping plan; 3. Emergency operating plan; 4. Grazing management plan; 5. Irrigation management and scheduling plan; 6. Nuisance and Odor management plan; 7. Runoff management plan; 8. Well location acceptability analysis; 9. Waste solids management plan The PO shall be updated as needed to reflect current operations. The permittee shall notify DEQ of material changes to the PO and copies must be kept on site and made available to DEQ upon request.

<table>
<tr><th>Compliance Activity (CA) Number and Completion Due Date</th><th>Compliance Activity Description</th></tr>
<tr><td>CA-998-02

Twelve (12) months after permit issuance</td><td>Quality Assurance Project Plan (QAPP): The permittee shall prepare and implement a QAPP that incorporates all monitoring and reporting required by this permit. A copy of the QAPP along with written notice that the permittee has implemented the QAPP shall be provided to DEQ.

The QAPP shall be designed to assist in planning for the collection, analysis, and reporting of all monitoring in support of this permit and in explaining data anomalies when they occur. At a minimum, the QAPP must include the following:

1. Details on the number of measurements, number of samples, type of sample containers, preservation of samples, holding times, analytical methods, analytical detection and quantitation limits for each target compound, type and number of quality assurance field samples, precision and accuracy requirements, sample preparation requirements, sample shipping methods, and laboratory data delivery requirements.
2. Maps indicating the location of each monitoring, and sampling point.
3. Qualification and training of personnel.
4. Names, addresses and telephone numbers of the laboratories used by or proposed to be used by the permittee.
5. Example formats and tables that will be used by the permittee to summarize and present all data in the Annual Report.

The format and the content of the QAPP should adhere to the recommendations and references in the Quality Assurance and Data Processing sections of the DEQ Guidance.

The permittee shall amend the QAPP whenever there is a modification in sample collection, sample analysis, or other procedure addressed by the QAPP. The permittee shall notify DEQ of material changes to the QAPP and copies must be kept on site and made available to DEQ upon request.</td></tr>
<tr><td>CA-998-03

One (1) year prior to the expiration date of this permit</td><td>Pre-Application Workshop: If the permittee intends to continue operating the reuse facility beyond the expiration date of this permit, the permittee shall contact DEQ and schedule a pre-application workshop to discuss the compliance status of the facility and the content required for the reuse permit application package.</td></tr>
<tr><td>CA-998-04

180 days prior to the expiration date of this permit</td><td>Renewal Permit Application: The permittee shall submit to DEQ a complete permit renewal application package, which fulfills the requirements specified at the pre-application workshop identified in CA-999-04.</td></tr>
</table>

4. Permit Limits and Conditions

4.1 Hydraulic Management Unit Descriptions

Serial Number	Description	Irrigation System Type and Irrigation Efficiency (E_i)	Maximum Acres[a] Allowed
MU-998-01	Thompson Field	Wheel Line: (E_i = 0.75)	75
MU-998-02	Metcalf Field	Solid Set: (E_i = 0.75)	50
MU-998-03	Pivot 1	Pivot: (E_i = 0.85)	150
MU-998-04	Pivot 2	Pivot: (E_i = 0.85)	150
		Total acreage	400

a. Maximum acres represent the total permitted acreage of the MU as provided by the permittee. If the permittee uses less acreage in any season or year, then loading rates shall be presented and compliance shall be determined based on the actual acreage utilized during each season or year.

4.2 Hydraulic Loading Limits

Serial Number	Growing Season Hydraulic Loading	Nongrowing Season Maximum Hydraulic Loading
MU-998-01 MU-998-02	Substantially at the irrigation water requirement (IWR)[a]	Not allowed
MU-998-03 MU-998-04	Substantially at the irrigation water requirement (IWR)[a]	November: 1.0 inches; 4.07 MG December: 0.8 inches; 3.26 MG January: 0.75 inches; 3.05 MG February: 0.75 inches; 3.05 MG March: 1.5 inches; 6.11 MG

a. For compliance purposes, the source of P_{def} data used to calculate the IWR shall be specified in the PO.

4.3 Constituent Loading Limits

Serial Number	Constituent Loading (from all sources)			
	Nitrogen (lb/acre)	Salt (NVDS) (lb/acre)	COD growing season (lb/acre-day)[a]	COD nongrowing season (lb/acre-day)[a]
MU-998-01 MU-998-02	150% of typical crop uptake[b]	None	50	None

MU-998-03 MU-998-04				25

a. COD limits are expressed in pounds per acre per day (lb/acre-day) based on a seasonal average.
b. Typical crop uptake is the median constituent crop uptake from the 3 most recent years the crop has been grown. For crops having less than 3 years of on-site crop uptake data, other crop yield data or nutrient content values may only be used if approved in writing by DEQ in advance of use. If written approval is not provided by DEQ, compliance with the 150% nitrogen loading limit shall be determined by comparing the current year nitrogen loading to the current year nitrogen uptake.

4.4 Management Unit Buffer Zones

Serial Number	Buffer Distances (in feet) from Management Units					
	Public Water Supplies	Private Water Supplies	Inhabited Dwellings	Permanent and Intermittent Surface Water	Irrigation Ditches and Canals	Areas Accessible to the Public
MU-998-01 MU-998-02 MU-998-03 MU-998-04	1,000	500	300	100	50	50

4.5 Other Permit Limits and Conditions

Category	Permit Limits and Conditions
Growing season	April 1 through October 31 (214 days)
Nongrowing season	November 1 through March 31 (151 days)
Reporting year for annual loading rates	November 1 through October 31
Crop or vegetation restrictions	Restricted to crops not grown for direct human consumption (crops must be processed prior to human consumption).
Grazing	Prior to grazing, the permittee shall submit a grazing management plan to DEQ and receive written approval from DEQ.
Posting & Fencing	Not Required

Category	Permit Limits and Conditions
Construction Plans	Pursuant to Idaho Code §39-118, IDAPA 58.01.16, and IDAPA 58.01.17, detailed plans and specifications shall be submitted to DEQ for review and approval prior to construction, modification, or expansion of any wastewater treatment, storage, conveyance structures, or reuse facility. Inspection requirements shall be satisfied and within 30 days of completion of construction and the permittee shall submit as-built plans or a letter from an Idaho Professional Engineer certifying the facilities or structures were constructed in substantial accordance with the approved plans and specifications.
Backflow prevention and testing requirements	Backflow prevention is required to protect surface water and ground water from an unauthorized discharge of recycled water or wastewater. Refer to section 9.1.1 of this permit.
Records retention requirements	Keep records generated to meet the requirements of this permit for the duration of the permit, including administrative extensions, plus 2 years.

5. Monitoring Requirements

5.1 Recycled Water and Supplemental Irrigation Water Sampling and Analyses

5.1.1 Constituent Monitoring

Monitoring Point Serial Number and Location	Sample Description	Sample Type and Frequency	Constituents (Units in mg/L Unless Otherwise Specified)
WW-998-01 Recycled water from clarifier at pumping station sample port	Wastewater quality to all management units (during periods of recycled water land application)	Grab/monthly	- Chemical oxygen demand - Total Kjeldahl nitrogen - Nitrate + nitrite nitrogen - Total phosphorus - pH - Total dissolved solids (TDS) - Volatile dissolved solids (VDS) - Sulfate
SW-998-01 Irrigation well sample port	Supplemental irrigation water quality to all management units	Grab/annually: May	- Nitrate-nitrogen - Total phosphorus - Total dissolved solids (TDS) - Volatile dissolved solids (VDS) - pH - Sulfate

5.1.2 Management Unit and Other Flow Monitoring

Management Unit or Flow Measurement Serial Number and Location	Sample Description	Sample Type and Frequency	Measured Parameter, each MU
MU-998-01 MU-998-02 MU-998-03 MU-998-04	Recycled water flow from clarifier	- Daily meter reading; - Monthly compilation of data; (during periods of reuse water land application)	- Volume (MG/month) - Application depth (inches/month)
MU-998-01 MU-998-02 MU-998-03 MU-998-04	Supplemental irrigation water from irrigation well #1	- Daily meter reading; - Monthly compilation of data; (during periods of supplemental irrigation)	- Volume (MG/month) - Application depth (inches/month)
FM-998-01	Wastewater influent volume	- Daily meter reading; - Monthly compilation of data	- Volume (MG/month) - Volume (MG/year)

5.2 Ground Water Monitoring

5.2.1 Ground Water Monitoring Point Descriptions

Monitoring Point Serial Number	Common Designation	Well Type	Gradient Location
GW-998-01	MW-1	Monitoring well	Upgradient
GW-998-02	MW-2	Monitoring well	Downgradient
GW-998-03	MW-3	Monitoring well	Downgradient
GW-998-04	Private Well[a]	Domestic well	Downgradient

a. Obtain owner permission prior to sampling. Written documentation shall be provided if owner declines to have the well sampled.

5.2.2 Ground Water Monitoring, Sampling, and Analyses

Monitoring Point Serial Number	Sampling Point Description	Sample Type and Frequency	Constituents (Units in mg/L Unless Otherwise Specified)
GW-998-01 GW-998-02 GW-998-03	Monitoring wells	Unfiltered grab sample / twice annually: April, October	- Water table elevation (ft) - Water table depth (ft) - Nitrate-nitrogen, as N - Chloride - Total coliform/100 mL
GW-998-04	Domestic well (monitored contingent on owner's permission)	Unfiltered grab sample/October of 2020 and 2024	- Sodium - Potassium - Calcium - Magnesium - Sulfate, as S - Chloride - Alkalinity (as $CaCO_3$)

5.3 Soil Monitoring

5.3.1 Soil Monitoring Unit Descriptions

Monitoring Point Serial Number	Description	Associated Management Unit
SU-998-01	Thompson Field	MU-998-01
SU-998-02	Metcalf Field	MU-998-02
SU-998-03	Pivot 1	MU-998-03
SU-998-04	Pivot 2	MU-998-04

5.3.2 Soil Monitoring, Sampling, and Analyses

Monitoring Point Serial Number	Sample Type	Sample Frequency	Constituents (Units in mg/kg Soil Unless Otherwise Specified)
SU-998-01 SU-998-02 SU-998-03 SU-998-04	Composite samples[a]	Annually: April (during periods of reuse water land application)	- Electrical conductivity (umhos/cm in saturated paste extract) - Nitrate-nitrogen - Ammonium-nitrogen - Plant available phosphorus (Olsen method – soils with pH 6.5 or greater, Bray method – soils with pH less than 6.5) - pH (standard units)

a. The number of sample locations specified in the PO or QAPP for each SU shall be sampled. At each location, samples shall be obtained from three depths: 0–12 inches; 12–24 inches; and 24–36 inches or refusal. The samples obtained from each depth shall be composited by depth to yield three composite samples for each soil monitoring unit; one composite sample for each depth.

5.4 Plant Tissue Monitoring

5.4.1 Crop Harvest Monitoring

Associated Hydraulic Management Units	Sample Type	Sample Frequency	Parameters[a]
MU-998-01 MU-998-02 MU-998-03 MU-998-04	Harvested portion, each crop, each MU	Each harvest	- Crop Type - Harvest Date - Sample Collection Date - Harvest acreage (acres) - As-harvested (‘wet’) Yield in customary harvested units (tons, bushels, cwt, etc.) - As-harvested (field) moisture content (%) - Dry Yield (lbs)

a. Documentation of reported yields shall be provided for each harvest from each MU.

5.4.2 Plant Tissue Monitoring

Associated Hydraulic Management Units	Sample Type	Sample Frequency	Parameters[a]
MU-998-01 MU-998-02 MU-998-03 MU-998-04	Harvested portion, each crop, each harvest	Each harvest	- Moisture content (%) - Total Kjeldahl nitrogen (%) - Nitrate nitrogen, as N (ppm) - Phosphorus as P (ppm) - Ash (%)

a. Report dry-basis results for all parameters except lab moisture content.

5.5 Lagoon Information

Serial number	Description	Surface Area (acres)	Maximum Operating Volume (MG)	Liner Type
LG-998-01	Storage Lagoon	0.5	1	HDPE

6. Reporting Requirements

6.1 Annual Report Requirements

The permittee shall submit to DEQ an Annual Report prepared by a competent environmental professional covering the previous reporting year.

6.1.1 Due Date

The Annual Report is due no later than January 31 of each year, which shall cover the previous reporting year.

6.1.2 Required Contents

The Annual Report shall include the following:

1. A brief interpretive discussion of all required monitoring data. The discussion shall address data quality objectives, validation, and verification; permit compliance; and reuse facility environmental impacts. The reporting year for this permit is specified in section 4.5.
2. Results of the required monitoring as described in section 5 of this permit. If the permittee monitors any parameter for compliance purposes more frequently than required by this permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the Annual Report. The report shall present all monitoring data in organized data summary tables to expedite review.
3. Status of all work described in section 3 of this permit.
4. Results of all backflow testing, repairs, and replacements required by Section 9.1.1 of this permit.
5. Discussion of major maintenance activities such as major equipment replacement, liner maintenance, and wastewater treatment and reuse facility maintenance.
6. A summary of all noncompliance events that occurred during the reporting year. Examples of noncompliance events that must be discussed include, but are not limited to: complaints, missed monitoring events, incorrect monitoring dates or frequencies, dry monitoring wells, uncontained spills causing runoff, construction without DEQ engineering plan approval, construction without engineering inspection, and reporting incorrect acreage.
7. Submittal of the calculations and observations for hydraulic management units specified in the table below.
8. All laboratory analytical reports, chain of custody forms, and crop yield documentation.
9. The parameters in the following table:

Monitoring Point Serial Number	Parameter (Calculate for each MU)	Units
MU-998-01 MU-998-02 MU-998-03 MU-998-04	Recycled water loading rate	Million gallons/month Inches/month
	Irrigation water loading rate	Million gallons/month Inches/month
	Irrigation water requirement (IWR) for each crop	Inches/month Inches/GS
	COD loading rate: growing season seasonal average	Pounds/acre-day
	COD loading rate: nongrowing season seasonal average	Pounds/acre-day
	Recycled water nitrogen, phosphorus and NVDS loading rates	Pounds/acre-year
	Supplemental Irrigation water nitrogen, phosphorus and NVDS loading rates	Pounds/acre-year
	Fertilizer nitrogen and phosphorus application rates, reported as elemental N and P	Pounds/acre-year
	Waste solids nitrogen and phosphorus application rates	Pounds/acre-year
	Crop Harvest and Yield Report each harvest and the annual totals for each MU.	Crop Types Harvested Total Harvested Area(acres/yr) Total 'wet' yield (lb/yr, lb/acre-yr) Total 'dry' yield (lb/yr, lb/acre-yr)
	Crop nitrogen, phosphorus, and ash removal rates (dry-basis) Report each harvest and the annual totals for each MU.	Pounds-N/acre-year Pounds-P/acre-year Pounds Ash/acre-year
Other Reporting Requirements: 2. Visual observation of field conditions: areas of ponding, ice, and unusual conditions.		

6.1.3 Submittal

All applications, annual reports, or information submitted to DEQ as required by this permit shall be signed and certified as follows:

1. Permit applications shall be signed by the Responsible Official as follows:
    a. For a corporation: by a responsible corporate officer;
    b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively;

   c. For a municipality, state, federal, Indian tribe, or other public agency: by either the principal executive officer or ranking elected official.

2. Annual reports and other information requested by DEQ shall be signed by the Responsible Official or by a duly Authorized Representative of that person. A person is a duly Authorized Representative only if:
   a. The authorization is made in writing by the responsible official;
   b. The authorization specifies either an individual or position having responsibility for the overall operation or the regulated facility, such as the position of plant manager, superintendent, position of equivalent responsibility, or an individual having overall responsibility for environmental matters for the company; and
   c. The written authorization is submitted to DEQ.

Submit the annual report to the following DEQ regional office at this address:

Engineering Manager
Idaho Department of Environmental Quality
Boise Regional Office
1445 N. Orchard
Boise, ID 83706

The annual report shall include the following certification statement and be signed, dated, and certified by the permittee’s Responsible Official or Authorized Representative:

> “*I certify that the information in this submittal was prepared in conformance with the Quality Assurance Project Plan required by permit M-998-02, and is to the best of my knowledge, true, accurate and complete and I acknowledge that knowing submission of false or incomplete information may result in permit revocation as provided for in IDAPA 58.01.17.920.01 or other enforcement action as provided for under Idaho law.”*

6.2 Emergency and Noncompliance Reporting

Report noncompliance incidents to DEQ’s regional office at (208) 373-0550 or 1-888-800-3480.

In case of emergencies, call the emergency 24-hour number at 1-800-632-8000 and DEQ’s regional office.

See Section 8, “Standard Permit Conditions,” and IDAPA 58.01.17.500.06 for reporting requirements for facilities.

All instances of unpermitted discharges of wastewater to Surface Waters of the United States shall also be reported to the Environmental Protection Agency by telephone within 24 hours from the time the permittee becomes aware of the discharge and in writing within five days at this address:

NPDES/Stormwater Coordinator, USEPA Idaho Operations Office
950 W. Bannock, Suite 900
Boise, ID 83702
208-378-5746 / 208-378-5744 and EPA Hot Line (206) 553-1846

7. Permit for Use of Industrial Recycled Water

The following are permit requirements for industrial recycled water and are included as terms of this permit as required by the "Recycled Water Rules," (**IDAPA 58.01.17.616).**

616. PERMIT FOR USE OF INDUSTRIAL RECYCLED WATER.

Industrial recycled water shall only be used in accordance with a permit issued pursuant to these rules. Permit conditions and limitations shall be developed by the Department on a case-by-case basis taking into account the specific characteristics of the wastewater to be recycled, the treatment necessary to ensure the use of such recycled water is in compliance with IDAPA 58.01.11, "Ground Water Quality Rule" and IDAPA 58.01.02, "Water Quality Standards." Unless otherwise indicated in this section, the permit application, processing and issuance procedures provided in this rule shall apply to industrial reuse permits. (4-7-11)

8. Standard Permit Conditions

The following standard permit conditions are included as terms of this permit as required by the "Recycled Water Rules," (**IDAPA 58.01.17.500).**

500. STANDARD PERMIT CONDITIONS.

The following conditions shall apply to and be included in all permits. (4-1-88)

01. Compliance Required. The permittee shall comply with all conditions of the permit. (4-1-88)

02. Renewal Responsibilities. If the permittee intends to continue operation of the permitted facility after the expiration of an existing permit, the permittee shall apply for a new permit in accordance with these rules. (4-1-88)

03. Operation of Facilities. The permittee shall at all times properly maintain and operate all structures, systems, and equipment for treatment, control and monitoring, which are installed or used by the permittee to achieve compliance with the permit or these rules. (4-1-88)

04. Provide Information. The permittee shall furnish to the Director within a reasonable time, any information including copies of records, which may be requested by the Director to determine whether cause exists for modifying, revoking, re-issuing, or terminating the permit, or to determine compliance with the permit or these rules. (4-1-88)

05. Entry and Access. The permittee shall allow the Director, consistent with Title 39, Chapter 1, Idaho Code, to: (4-1-88)

a. Enter the permitted facility. (4-1-88)

b. Inspect any records that must be kept under the conditions of the permit. (4-1-88)

c. Inspect any facility, equipment, practice, or operation permitted or required by the permit. (4-1-88)

d. Sample or monitor for the purpose of assuring permit compliance, any substance or any parameter at the facility. (4-1-88)

06. Reporting. The permittee shall report to the Director under the circumstances and in the manner specified in this section: (4-1-88)

a. In writing at least thirty (30) days before any planned physical alteration or addition to the permitted facility or activity if that alteration or addition would result in any significant change in information that was submitted during the permit application process. When the alteration or addition results in a need for a major modification, such alteration or addition shall not be made prior to Department approval issued in accordance with these rules. (4-7-11)

b. In writing thirty (30) days before any anticipated change which would result in noncompliance with any permit condition or these rules. (4-1-88)

c. Orally within twenty-four (24) hours from the time the permittee became aware of any noncompliance which may endanger the public health or the environment at telephone numbers provided in the permit by the Director. (4-1-88)

d. In writing as soon as possible but within five (5) days of the date the permittee knows or should know of any noncompliance unless extended by the Department. This report shall contain: (4-1-88)

i. A description of the noncompliance and its cause; (4-1-88)

ii. The period of noncompliance including to the extent possible, times and dates and, if the noncompliance has not been corrected, the anticipated length of time it is expected to continue; and (4-7-11)

iii. Steps taken or planned, including timelines, to reduce or eliminate the continuance or reoccurrence of the noncompliance. (4-7-11)

e. In writing as soon as possible after the permittee becomes aware of relevant facts not submitted or incorrect information submitted, in a permit application or any report to the Director. Those facts or the correct information shall be included as a part of this report. (4-1-88)

07. Minimize Impacts. The permittee shall take all necessary actions to eliminate and correct any adverse impact on the public health or the environment resulting from permit noncompliance. (4-1-88)

08. Compliance with "Ground Water Quality Rule." Permits issued pursuant to these rules shall require compliance with IDAPA 58.01.11, "Ground Water Quality Rule." (4-7-11)

9. General Permit Conditions

The following general permit conditions are based on the cited rules at the time of issuance and are enforceable as part of this permit. Note that the rules cited in this section, and elsewhere in this permit, are supplemented by the rules themselves. Rules applicable to your facility are enforceable whether or not they appear in this permit.

9.1 Operations

9.1.1 Backflow Prevention

Reuse facilities with existing or planned cross-connections or interconnections between the recycled water system and any water supply (potable or nonpotable), or surface water, shall have backflow prevention assemblies, devices, or methods as required by the applicable rule or as specified in this permit and approved by DEQ.

For public water systems, backflow assemblies shall meet the requirements of IDAPA 58.01.08.543. Assemblies shall be adequately maintained and shall be tested annually by a certified backflow assembly tester, and repaired or replaced as necessary to maintain operational status.

For domestic water supply wells, backflow prevention devices shall meet the requirements of IDAPA 07.02.04 and shall be adequately operated and maintained.

Irrigation water supply wells shall meet the requirements of IDAPA 37.03.09.36 for preventing any waste or contamination of the ground water resource. Backflow prevention assemblies or devices used to protect the ground water shall be adequately operated and maintained.

Discharge of recycled water to surface water is regulated by the EPA NPDES program. An NPDES permit is required for any discharge to surface water and backflow prevention shall be implemented to prevent any unauthorized discharge. Backflow prevention assemblies or devices used to protect the ground water shall be adequately operated and maintained.

Records of all testable backflow assembly test results, repairs, and replacements shall be kept at the reuse facility along with other operational records, and shall be discussed in the Annual Report and made available for inspection by DEQ. Other approved means of backflow prevention, such as siphons and air-gap structures that cannot be tested, shall be maintained in operable order.

9.1.2 Restricted to Premises

Wastewaters or recharge waters applied to the land surface must be restricted to the premises of the application site. Wastewater discharges to surface water that require a permit under the Clean Water Act must be authorized by the United States Environmental Protection Agency (IDAPA 58.01.16.600.02).

9.1.3 Health Hazards, Nuisances, and Odors Prohibited

Health hazards, nuisances, and odors are prohibited as follows:

- Wastewater must not create a public health hazard or nuisance condition (IDAPA 58.01.16.600.03).
- No person shall allow, suffer, cause or permit the emission of odorous gases, liquids, or solids into the atmosphere in such quantities as to cause air pollution (IDAPA 58.01.01.776.01).
- Air Pollution. The presence in the outdoor atmosphere of any air pollutant or combination thereof in such quantity of such nature and duration and under such conditions as would be injurious to human health or welfare, to animal or plant life, or to property, or to interfere unreasonably with the enjoyment of life or property (IDAPA 58.01.01.006.06).

9.1.4 Solids Management

Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge. When treated and processed, sewage sludge becomes biosolids which can be safely recycled and applied as fertilizer to sustainably improve and maintain productive soils and stimulate plant growth.

Biosolids generated from sewage sludge are regulated by EPA under 40 CFR Part 503 and require a DEQ approved sludge disposal plan as outlined in IDAPA 58.01.16.650. Contact DEQ prior to application of biosolids at any permitted reuse facility.

Sludge is the semi-liquid mass produced and removed by wastewater treatment processes. This does not include grit, garbage, and large solids.

Sludge is generated by wastewater treatment processes at municipal and industrial facilities.

Solid Waste is any garbage or refuse, sludge from a waste water treatment plant, water supply treatment plant, or air pollution control facility and other discarded material including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved material in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended or source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended.

Solid waste does not include inert wastes, manures and crop residues ultimately returned to the soils at agronomic rates, and any agricultural solid waste which is managed and regulated pursuant to rules adopted by the Idaho Department of Agriculture. DEQ reserves the right to use existing authorities to regulate agricultural waste that impacts human health or the environment.

Solid waste is regulated under “Solid Waste Management Rules”, IDAPA 58.01.06. Wastes otherwise regulated by DEQ (i.e. this permit) are not regulated under 58.01.06.

Waste Solids include sludge and wastes otherwise regulated by DEQ in accordance with IDAPA 58.01.06.001.03.a.xii. Waste solids may include vegetative waste, silt and mud containing organic matter, and other non-inert solid wastes.

Inert wastes are defined as non-combustible, nonhazardous, and non-putrescible solids wastes that are likely to retain their physical and chemical structure and have a de minimis potential to generate leachate under expected conditions of disposal, which includes resistance to biological attack.

Waste solids require a DEQ approved sludge disposal plan as outlined in IDAPA 58.01.16.650.

9.1.5 Temporary Cessation of Operations and Closure (IDAPA 58.01.17.801)

Temporary cessation of operations and closure must be addressed as follows:

01. Temporary Cessation. A permittee shall implement any applicable conditions specified in the permit for temporary cessation of operations. When the permit does not specify applicable temporary cessation conditions, the permittee shall notify the Director prior to a temporary cessation of operations at the facility greater than sixty (60) days in duration and any cessation not for regular maintenance or repair. Cessation of operations necessary for regular maintenance or repair of a duration of sixty (60) days or less are not required to notify the Department under this section. All notifications required under this section shall include a proposed temporary cessation plan that will ensure the cessation of operations will not pose a threat to human health or the environment. (4-7-11)

02. Closure. A closure plan shall be required when a facility is closed voluntarily and when a permit is revoked or expires. A permittee shall implement any applicable conditions specified in the permit for closure of the facility. Unless otherwise directed by the terms of the permit or by the Director, the permittee shall submit a closure plan to the Director for approval at least ninety (90) days prior to ceasing operations. The closure plan shall ensure that the closed facility will not pose a threat to human health and the environment. Closure plan approval may be conditioned upon a permittee's agreement to complete such site investigations, monitoring, and any necessary remediation activities that may be required. (4-7-11)

9.1.6 Plan of Operation (IDAPA 58.01.17.300.05)

The PO must comply with the following:

05. Reuse Facility Operation and Maintenance Manual or Plan of Operations. A facility's operation and maintenance manual must contain all system components relating to the reuse facility in order to comply with IDAPA 58.01.16 "Wastewater Rules," Section 425. Manuals and manual amendments are subject to the review and approval provision therein. In addition to the content required by IDAPA 58.01.16.425, manuals for reuse facilities shall include, if applicable: operation and management responsibility, permits and standards, general plant description, operation and control of unit operations, land application site maps, wastewater characterization, cropping plan, hydraulic loading rate, constituent loading rates, compliance activities, seepage rate testing, site management plans, monitoring, site operations and maintenance, solids handling and processing, laboratory testing, general maintenance, records and reports, store room and inventory, personnel, an emergency operating plan, and any other information required by the Department. (4-7-11)

9.1.7 Reserved

9.1.8 Ground Water Quality (IDAPA 58.01.11)

The permittee shall comply with the requirements of "Ground Water Quality Rule" (IDAPA 58.01.11).

9.2 Administrative

Requirements for administration of the permit are defined as follows.

9.2.1 Permit Modification (IDAPA 58.01.17.700)

01. Modification of Permits. A permit modification may be initiated by the receipt of a request for modification from the permittee, or may be initiated by the Department if one (1) of more of the following causes for modification exist: (4-7-11)

a. Alterations. There are material and substantial alterations or additions to the permitted facility or activity which occurred after permit issuance which justify the application of permit conditions that are different or absent in the existing permit. (4-7-11)

b. New standards or regulations. The standards or regulations on which the permit was based have been changed by promulgation of amended standards or regulations or by judicial decision after the permit was issued. (4-7-11)

c. Compliance schedules. The Department determines good cause exists for modification of a compliance schedule or terms and conditions of a permit. (4-7-11)

d. Non-limited pollutants. When the level of discharge of any pollutant which is not limited in the permit exceeds the level which may cause an adverse impact to surface or ground waters. (4-7-11)

e. To correct technical mistakes, such as errors in calculation, or mistaken interpretations of law made in determining permit conditions. (4-7-11)

f. When a treatment technology proposed, installed, and properly operated and maintained by the permittee fails to achieve the requirements of the permit. (4-7-11)

9.2.2 Permit Transferable (IDAPA 58.01.17.800)

01. General. A permit may be transferred only upon approval of the Department. No transfer is required for a corporate name change as long as the secretary of state can verify that a change in name alone has occurred. An attempted transfer is not effective for any purpose until approved in writing by the Department. (4-7-11)

9.2.3 Permit Revocation (IDAPA 58.01.17.920)

01. Conditions for Revocation. The Director may revoke a permit if the permittee violates any permit condition or these rules, or the Director becomes aware of any omission or misrepresentation of condition or information relied upon when issuing the permit. (4-7-11)

02. Notice of Revocation. Except in cases of emergency, the Director shall issue a written notice of intent to revoke to the permittee prior to final revocation. Revocation shall become final within thirty-five (35) days of receipt of the notice by the permittee, unless within that time the permittee requests an administrative hearing in writing. The hearing shall be conducted in accordance with IDAPA 58.01.23, Rules of Administrative Procedure Before the Board of Environmental Quality." (5-3-03)

03. Emergency Action. If the Director finds the public health, safety or welfare requires emergency action, the Director shall incorporate findings in support of such action in a written notice of emergency revocation issued to the permittee. Emergency revocation shall be effective upon receipt by the permittee. Thereafter, if requested by the permittee in writing, the Director shall provide the permittee a revocation hearing and prior notice thereof. Such hearings shall be conducted in accordance with IDAPA 58.01.23, Rules of Administrative Procedure Before the Board of Environmental Quality." (3-15-02)

04. Revocation and Closure. A permittee shall perform the closure requirements in a permit, the closure requirements of these rules, and complete all closure plan activities notwithstanding the revocation of the permit. (4-7-11)

9.2.4 Violations (IDAPA 58.01.17.930)

Any person violating any provision of these rules or any permit or order issued thereunder shall be liable for a civil penalty not to exceed ten thousand dollars ($10,000) or one thousand dollars ($1,000) for each day of a continuing violation, whichever is greater. In addition, pursuant to Title 39, Chapter 1, Idaho Code, any willful or negligent violation may constitute a misdemeanor. (4-1-88)

9.2.5 Severability

The provisions of this permit are severable, and if a provision or its application is declared invalid or unenforceable for any reason, that declaration will not affect the validity or enforceability of the remaining provisions.

9.3 Other Applicable Laws

DEQ may refer enforcement of the following provisions to the state agency authorized to enforce that rule. The permittee shall comply with all applicable provisions identified in this section, as well as all other applicable federal, state, and local laws, statutes, and rules.

9.4 Owner Responsibilities for Well Use and Maintenance

9.4.1 Well Use

The well owner must not operate any well in a manner that causes waste or contamination of the ground water resource. Failure to operate, maintain, knowingly allow the construction of any well in a manner that violates these rules, or failure to repair or properly decommission (abandon) any well as herein required will subject the well owner to civil penalties as provided by statute. See IDAPA 37.03.09.036.01 and consult the Idaho Department of Water Resources (IDWR) for more information.

9.4.2 Well Maintenance

The well owner must maintain the well to prevent waste or contamination of ground waters through leaky casings, pipes, fittings, valves, pumps, seals, or through leakage around the outside of the casings, whether the leakage is above or below the land surface. Any person owning or controlling a noncompliant well must have the well repaired by a licensed well driller under a permit issued by the IDWR director in accordance with the applicable rules. See IDAPA 37.03.09.036.02 and consult IDWR for more information.

9.4.3 Wells Posing a Threat to Human Health and Safety or Causing Contamination of the Ground Water Resource

The well owner must have any well shown to pose a threat to human health and safety or cause contamination of the ground water resource immediately repaired or decommissioned (abandoned) by a licensed well driller under a permit issued by the IDWR director in accordance with the applicable rules. See IDAPA 37.03.09.036.06 and consult the IDWR for more information.

9.5 Site Maps

9.6 Regional Map

This map is designed to show the reuse site in relation to major surrounding features such as cities, water bodies, highways and roads, county boundaries, state boundaries, etc…

9.7 Facility Map(s)

This map will contain at a minimum, hydraulic management units (boundaries and size in acres), ground water monitoring wells, and lagoons.

Other features that may be included are public water supply(s), private wells, surface waters, public roads, and waste solids storage or application areas.

Note:

Other maps and figures can be included if necessary to interpret the reuse permit:

- Soil management unit map when soil management units do not coincide with hydraulic management unit boundaries (including NRCS soil maps)
- Ground water flow contour maps
- Location of other environmental monitoring points (influent wastewater, surface water, specific flow measurement locations, etc.

Appendix B. Monitoring Well Construction Guidance

The following is an excerpt from the *Guidance for Land Application of Municipal and Industrial Wastewater*, which can be accessed in its entirety at *http://www.deq.idaho.gov/media/516329-guidance_reuse_0907.pdf.*

7.2.2 Monitoring Well Network Design

The second phase consists of installation of monitoring wells. These wells are designed to measure the impact of land treatment systems on ground water, in locations based on observation well data. The number of required monitoring wells will depend on site specific characteristics such as the number of hydraulic management units and/or acres and the number of irrigation pivots or other irrigation systems used to distribute wastewater. Generally, large land application sites with complex hydrogeology may require more monitoring wells than sites that are small or hydrogeologically simple. The number of well installations also depends on the type of monitoring requirements. Land application sites with a long downgradient boundary perpendicular to the ground water flow direction may require additional monitoring wells.

Monitoring wells should be installed so that there are at least one (1) up gradient and two (2) down gradient of the land treatment site in water bearing zones which could transmit contaminants. The wells should be screened in the same aquifer, and generally should be completed in the first encountered water below land surface. This well array can be used to determine ground water flow direction, as well as for sample collection. Specific guidance on well construction practices is found in Section 7.2.3 below.

7.2.3 Monitoring Well Construction

This section provides guidance on monitoring well construction practices for wastewater land application facilities. This monitoring well construction guidance is not applicable for sites where hazardous materials are known to exist, or where nested or paired wells are required to investigate water chemistry variations at differing depths in an aquifer or in two or more separate aquifers.

Specific installation procedures for ground water monitoring wells may be found in the Idaho Department of Water Resources Rules and Regulations for Well Construction Standards (January 1989), Ogden (1987), Winter (1993), and EPA (1986).

Knowledge of the water quality of the well as it is being constructed is highly desirable. Such knowledge can affect decisions regarding continued construction, modifications in construction, selection of materials or in the planned operations of the completed well. Common problems related to well construction and water quality monitoring include water zones to be excluded by casing or grouting; selected casing perforation; choice of casing and screen material; and screen placement.

At wastewater land application facilities, ground water samples should be collected as close to the top of the water table as practical, since this is where contaminants that migrate to the water table will be most concentrated. Wells may be required for each subsequent aquifer beneath the uppermost water table, however. A properly constructed monitoring well should meet the following criteria. Refer to Figures 6 and 7 for construction and completion details. Additional guidance is available from ASTM D 5092-90.

- All monitoring well construction must conform to the well construction rules listed in Idaho Administrative Procedures Act (IDAPA) 37.03.09.

- Monitoring wells more than 18 feet in vertical depth that are constructed to evaluate, observe or determine the quality, quantity, temperature, pressure or other characteristics of the ground water or aquifer require a permit to be issued by the Idaho Department of Water Resources
- Monitoring wells 18 feet deep or less also should conform to the well construction rules listed in IDAPA 37.03.09
- The siting of monitoring wells in relation to a wastewater land treatment site and other possible sources of contamination should be coordinated with DEQ as part of the WLAP permitting process. Monitoring wells required as part of a subsurface sewage disposal system permit should be coordinated with the local District Health Department.
- Proposed monitoring well designs should be submitted to DEQ for review and approval prior to well construction.
- An adequate surface seal, generally 3 feet or more thick, should be provided around the outer protective casing to prevent migration of contaminants from the surface to the well screen. This surface seal should be sloped away from the well casing.
- The screen and sand pack material should be selected so that the well can be developed with minimal sediment production over the life of the well.
- The screened interval should be placed in the uppermost water-bearing zone. Monitoring wells should be screened in the top 10 to 15 feet of this uppermost water-bearing zone, with adequate screen above the water table to allow for seasonal water table fluctuations.
- In areas with extreme water table fluctuations, more than one monitoring well may be needed so that the water table can be adequately sampled. In this case, the upper and lower screens should be 10 to 15 feet in length. The bottom of the upper screen should end where the top of the lower screen begins.
- The sand pack should extend above the well screen to prevent entry of grout and/or bentonite into the screened interval.
- A sanitary seal should be placed above the filter pack. Bentonite chips or pellets are typically used to provide this seal.
- Grout (cement or bentonite) should be placed above the sanitary seal up to where the surface seal will begin.
- Well diameters are generally 2-inch or 4-inch, whichever is sufficient to accommodate the sampling pump. Two-inch or smaller casing material may be used for wells that are sampled using low-flow sampling methods.
- For wells that are purged using standard pumping methods, purge volumes should include the amount of water contained in the sand pack and inside the casing.
- Casing and screen material should be designed to last for the duration of the monitoring program. ASTM D 5092-90 may be used as a guide for selection of casing and screen material. Screen slot size should be determined relative to the interval to be monitored so that the well will produce sediment-free water for the life of the well.
- As-built diagrams along with a detailed geologic log should be provided to DEQ for each monitoring well. Certification of monitoring well construction in substantial accordance with as-built diagrams by an Idaho registered Professional Geologist or Professional Engineer, or someone under the direct supervision of an Idaho registered Professional Geologist or Professional Engineer should be provided to DEQ.

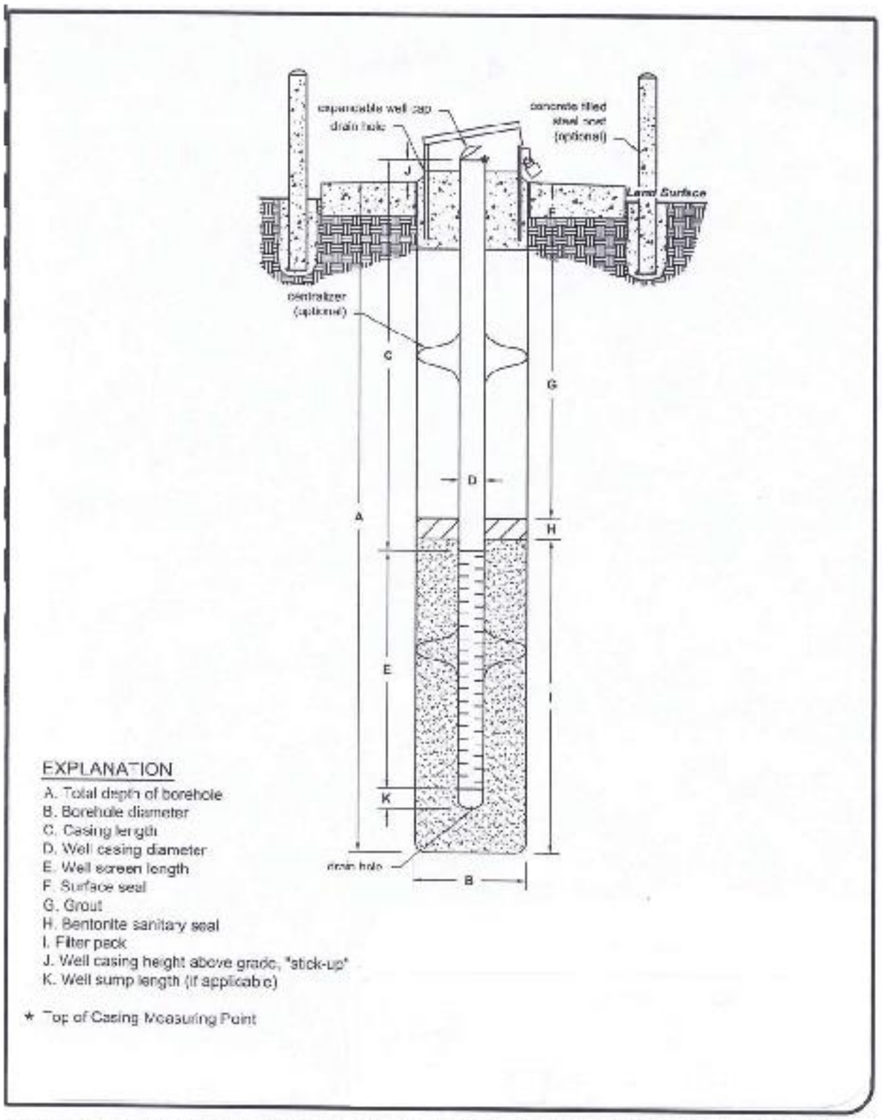

Figure 6. General monitoring well design for ground water sample collection at wastewater land application sites. (Monitoring well diagram reproduced by permission of Cascade Earth Sciences.)

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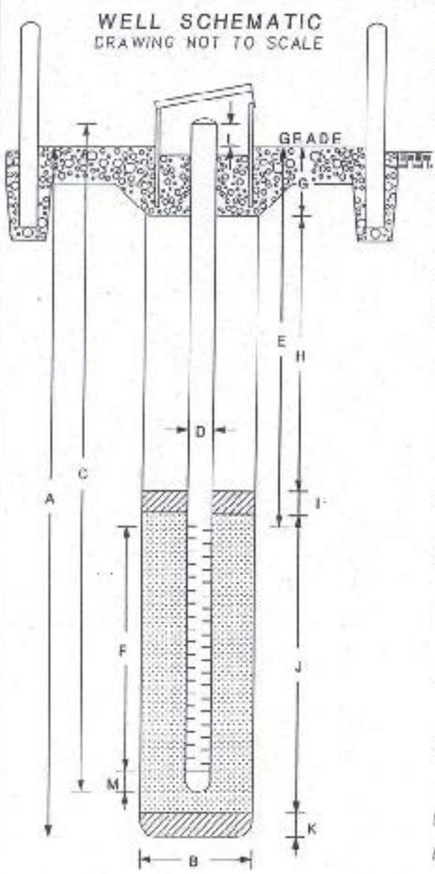
MONITORING WELL CONSTRUCTION DETAILS

PROJECT NAME ______
PROJECT NUMBER ______
DATE INSTALLED ______
WELL PERMIT NO. ______
LOCATION ______
NOTES: ______

BORING/WELL NO. ______
TOP OF CASING ELEV. AT MARK = ______
GROUND SURFACE ELEV. = ______
DATUM MEAN SEA LEVEL

WELL SCHEMATIC
DRAWING NOT TO SCALE



NOTE: Depths and intervals are measured from ground surface.

BORING INFORMATION

A. Total depth ft. 125.0

B. Diameter in. 10" 0–94' 6" 94–125'

Drilling method AIR ROTARY TRICONE

WELL CONSTRUCTION

C. Total Casing length ft. 125.0

Material SCH 40 PVC

D. Diameter (I.D.) in. 2.0

E. Depth to top perforations ft. 102.0

F. Perforated length ft. 20.0

Perforated interval from ft. 102.0 to ft. 122.0

Perforation size 0.010

G. Surface seal from 0.0 ft. to 3.0 ft.

Seal materials CONCRETE

H. Grout from 3.0 ft. to 84.0 ft.

Grout material CEMENT/BENTONITE GROUT

I. Sanitary seal from 84.0 ft. to 99.0 ft.

Seal materials BENTONITE PELLETS

J. Filter pack from 99.0 ft. to 122.0 ft.
10/20 FOR ERODED SAND ZONE

Pack material 20/40 CSSI SAND

K. Bottom zone 3.0 ft.

Material NATIVE FORMATION GRAVEL/SAND

L. Well casing ht. above grade 3.0 ft.

M. Well tail piece length 3.0 in.

Centralizers located at – ft. and – ft.

NOTES: –

Figure 7. As-built construction details for monitoring well at wastewater land application sites. (Monitoring well diagram reproduced by permission of Cascade Earth Sciences.)

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Appendix C. Reuse Permit: Annual Report Information Notes

The following details should be addressed in your annual report. For many of the questions, provide a narrative explaining what the data indicate is happening at the site and why you reached your conclusions.

1) Recycled Water/Irrigation Water Loading
   a) Is recycled water land applied within limits of the permit?
   b) Are recycled water loading calculations correct?
   c) Are only permitted sites being used for reuse land application?
   d) Is the growing season hydraulic loading (recycled water plus supplemental irrigation water) substantially at the irrigation water requirement (IWR)?
   e) Are nongrowing season recycled water loading rates within permitted limits?
2) Nutrient/Constituent Loading and Cropping
   a) Which nutrients and/or constituents have loading limits in the permit?
   b) Are nutrients/constituents land applied within limits of the permit?
   c) Are nutrient/constituent loading calculations correct?
   d) Are crops grown on reuse site with the recycled water land treatment acreage?
   e) Are crop yields typical for the region?
   f) Are crop uptake calculations done correctly?
3) Monitoring
   a) Which media are required to be sampled in the permit during this reporting period? (What are you monitoring?)
4) Ground Water Monitoring
   a) Is the facility reporting monitoring data as required in the permit?
   b) Are correct analytical procedures used?
   c) Do monitoring data indicate compliance with permit limits (and "Ground Water Quality Rule" [IDAPA 58.01.11] standards where applicable)?
   d) Has analyses/interpretation of ground water data been done? If yes, describe.
5) Recycled Water/Irrigation Water
   a) Is the facility reporting monitoring data as required in the permit?
   b) Are correct analytical procedures used?
   c) Are current water characteristics still as described in permit application materials?
   d) Which water constituents have concentration limits in the permit?
   e) Are constituent concentrations within limits of the permit?
   f) Has analyses/interpretation of wastewater/recycled water/irrigation water data been done? If yes, describe.
6) Soils
   a) Is the facility reporting monitoring data as required in the permit?

   b) Are correct analytical procedures used?
   c) Has analyses/interpretation of soils data been done? If yes, describe.
7) Plant Tissue Monitoring
   a) Is the facility reporting monitoring data as required in the permit?
   b) Are correct analytical procedures used?
   c) Has analyses/interpretation of plant tissue data been done? If yes, describe.
8) Other Monitoring
   a) Describe the other monitoring required.
   b) Is the facility reporting monitoring data as required in the permit?
   c) Are correct analytical procedures used?
   d) Has analyses/interpretation of other monitoring data been done? If yes, describe.
9) Other Permit Conditions, General Comments, and Recommendations
   a) Were acts of noncompliance reported as required by the permit?
   b) Was a compliance activity status update included in the annual report?
   c) Are there follow-up items from a previous annual report review?
   d) How were those follow-up items addressed?

Appendix D. Pumps and Motors

Before discussing specific types of pumps, it is important to understand the following general concepts of pumps and controls:

- Pump head
- Horsepower
- Pump capacity
- Pump performance curves

Head

Pumps are designed to deliver liquid against a specific pressure. Water has a specific weight (62.4 pounds per cubic foot or 8.34 pounds per gallon), and this weight resting on a surface exerts a force on that surface. Force on a specific area is called pressure. Pressure is the total load or force acting on a surface and is usually expressed in terms of pounds per square inch or pounds per square foot. Pressure can also be expressed in terms of feet of water, for its origin is the weight of a depth of water directly resting upon the area of measurement.

When pressure is measured in feet, it is called *head*. Pump head is defined as the resistance against which a pump will operate. A water column 100 feet high will exert a pressure of approximately 44 pounds per square inch. Conversely, 1 pound per square inch of pressure is equivalent to 2.31 feet of head.

In most cases, pumps are installed to provide the pressure necessary to move water from one location or elevation to another in a treatment system. Since the function of a pump is to add pressure to the system, the pressure on the discharge side of the pump will always be higher than the pressure on the suction side of the pump. In pump systems, measurements are taken from the point of reference to the centerline of the pump. Pump heads include both *static head* (when the pump is off) and *dynamic heads* (when the pump is on).

Horsepower

To purchase the appropriate pump for the job needed, it must be determined how much work the pump will be required to do and the rate at which the work will be done:

- *Work* is the operation of a force (pressure times area) over a specific distance, expressed in units of foot-pounds. One foot-pound is the amount of work required to lift a one pound object one foot off the ground.
- *Power* is the rate at which work is being done, and it is expressed as foot-pounds per second. Large units of power are called *horsepower*. One horsepower is 550 foot-pounds per second.

Motor, brake, and water horsepower are terms used to indicate where the horsepower is measured (Figure 1). Pumps are driven by motors, which are never 100% efficient; most motors are usually 80% to 90% efficient. *Motor horsepower* (mhp) is the horsepower applied to the motor in the form of electrical current. A portion of this horsepower is lost due to the conversion of electrical energy to mechanical energy.

Like motors, pumps are also not 100% efficient. *Pump efficiency* is the power produced by the unit, divided by the power used in operating the unit. Most pumps are 60%–85% efficient.

Brake horsepower (bhp) is the horsepower applied to the pump, or the power delivered to the pump shaft by the motor. Due to friction and slippage losses, more power is lost as the power moves through the pump.

Water horsepower (whp) is the actual horsepower available to pump water.

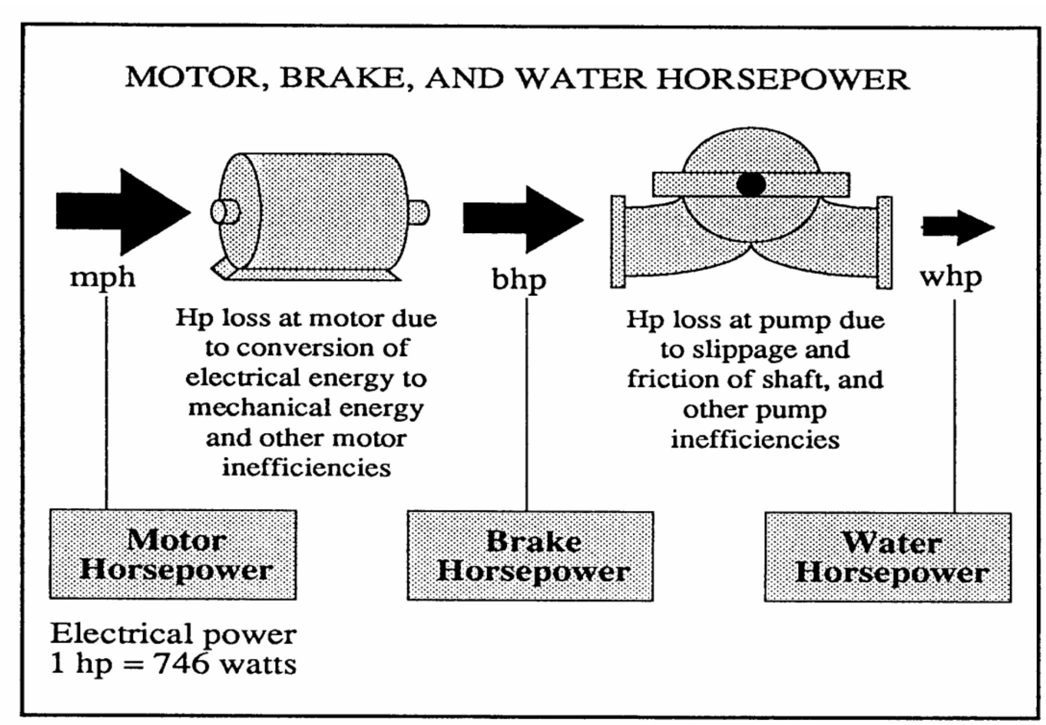

Figure 1. Motor, brake, and water horsepower (Applied Math for Wastewater Plant Operators 1991).

Motor, brake, and water horsepower can be calculated as Equations 1, 2, and 3:

$$\text{mhp} = \frac{\text{brake horsepower}}{\text{motor efficiency}}$$

Equation 1. Calculation of motor horsepower.

$$\text{bhp} = \frac{\text{water horsepower}}{\text{pump efficiency}}$$

Equation 2. Calculation of brake horsepower.

$$\text{whp} = \frac{\text{head (ft)} \times \text{flow (gpm)}}{3960}$$

Equation 3. Calculation of water horsepower.

Pump Capacity and Pump Delivery Rates

Each pump is designed to deliver a designated amount of flow against a specific head. This is the *design pump capacity* or *design pump delivery rate* (gallons per minute). However, actual pump capacity or delivery rates can vary, depending on the efficiency of a pump and the conditions under which it is operated.

The pump capacity and quantity of flow, in turn, determine the time required for each pumping or dosing cycle and the length of time between cycles. The amount of water pumped to a land application field during a pump cycle is called the *dosing volume* (gallons). The *pump delivery rate* is the amount of water pumped during a pump cycle divided by the pump run time (minutes). The *pump delivery rate efficiency* is the measured pump delivery rate (gallons per minute) divided by the design pump delivery rate times 100%.

Pump Performance

Pumps can deliver a wide range of flows, depending on design, speed, and total dynamic head. The best source of information on a particular pump is the manufacturer's pump performance curve, which provides information on discharge (flow), power requirements, and head characteristics.

Each pump is manufactured to operate most efficiently at a designated amount of head and flow. Operating a pump as close to peak efficiency as possible allows it to operate with the least amount of strain possible. Operating a pump well off peak efficiency can result in excessive energy requirements and shortened pump life.

To better understand the performance and operating characteristics of pumps, wastewater land application (WWLA) operators should become familiar with the pump curve that is supplied by the manufacturer for each pump. A pump curve shows the relationships between pump head, flow, efficiency, and horsepower. Pump curves can be used in case you need to modify your operating conditions from the original irrigation design. This may be necessary, for example, if you discover that the actual flow (discharge) exceeds the system design flow. A typical pump curve is shown in Figure 2.

Pump curves usually show three curves on one sheet:

- The *head-capacity curve* shows the discharge, in gallons per minute, the pump will deliver against various heads when operated at the proper speed. This curve shows that as the head increases, the discharge decreases, until there is no further discharge. Conversely, as head decreases, flow increases.
- The second curve, also plotted against flow, shows the *efficiency* at which the pump operates at various points on the head capacity curve. This curve shows that no pump is 100% efficient, due to internal friction losses. The highest efficiency that can be hoped for is around 85%. Efficiency can be expected to decrease with age and wear.
- The third curve, the *brake horsepower curve*, shows power consumed plotted against flow. If we know the total head at which the pump is operating, we can use the curve to find the gallons pumped. The power required by the pump, as well as the pump efficiency, can also be read from the curve for any set of conditions. This curve shows

that it usually takes more horsepower to pump more water: the lower the flow, the lower the horsepower required, and the higher the flow, the higher the horsepower required.

As discussed earlier, a pump operates most efficiently at the flow and head it was designed and rated for. This is sometimes called the design point or best efficiency point. This point normally falls in the middle of the pump performance curve. Operation at either extreme of the curve should be avoided. Operating a pump below the manufacturer's specified minimum head (at the high flow end of the curve) can result in overloading the motor. Operating a pump in the extreme high head region of the curve can result in decreased efficiency, increased noise and vibration, and low flows.

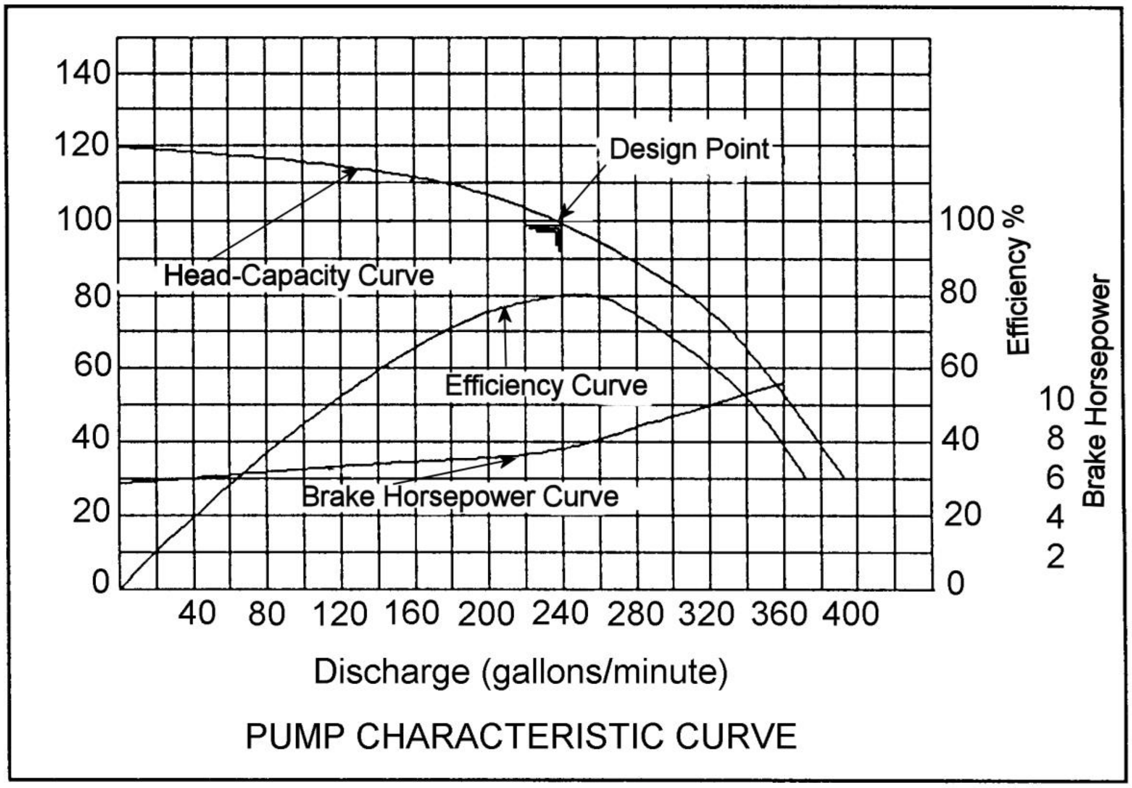

Figure 2. Pump characteristic curve (modified from Hauser 1991).

Pumps

There are a variety of pumps that you may encounter at your land application facility. Brief descriptions of some common pump types are provided below.

Centrifugal Pumps

Centrifugal pumps are radial flow pumps that can be used for most pumping activities. They consist of one or more impellers rotating in a casing, or *volute*. Impellers may be of the open, semiopen, or closed type. Open impellers are normally used for wastewater applications while closed impellers are normally used for irrigation waters that are relatively clean. Centrifugal pumps generally have a maximum suction of 34 feet. The practical suction is generally 20 feet or less.

Turbine Pumps

Turbine pumps are basically centrifugal pumps that are stacked on top of each other. Turbine pumps may have up to 25 stages, depending on the type of impellers used. Each stage adds pressure, not volume. These pumps are generally used for deep well irrigation systems or other applications where the intake is below the liquid level and where high discharge pressures are needed.

Submersible Pumps

Another type of centrifugal pump is the submersible pump. Submersible pumps are vertical, heavy-duty centrifugal pumps designed to work while immersed in the water that they are pumping. The watertight motor is also submerged. The surrounding water helps cool the pump and motor, extending their life and efficiency.

Reciprocating, Piston, or Plunger Pumps

Positive displacement pumps are usually associated with water that contains high levels of solids, and they must be operated with an open discharge valve. One such pump is the reciprocating pump. A reciprocating pump (also called a *piston* or *plunger* pump) moves wastewater or sludge by a piston or plunger that moves back and forth. This movement forces water from the suction side to the discharge side of the pump.

Because the movement of the plunger or piston creates pressure inside the pump, this kind of pump should never be operated against a closed discharge valve. To prevent a buildup of pressure that could damage the pump or burst pipes, all discharge valves must be open before the pump is started. Because force is exerted during the suction cycle, the suction valve should be always left at least partly open.

Diaphragm Pumps

Another type of positive displacement pump is the diaphragm pump, often used for chemical feed. Instead of using a piston or a plunger, a diaphragm (a flexible membrane) is used to force water from the suction to the discharge side of the pump. In a diaphragm pump, water does not come in contact with moving metal parts, an advantage over the reciprocating pump. This can be important when pumping abrasive or corrosive liquids.

Peristaltic Pumps

Peristaltic pumps are used for water sampling or chemical feed. Peristaltic pumps, the oldest pumps in existence, are another type of positive displacement pump. Water is moved through flexible tubing by advancing rollers that squeeze the tubing. Nothing but the tube touches the water, thus eliminating any risk of contamination. Pump design prevents backflow and siphoning without valves.

Pumping System Components

Pumping system components include the pump itself, electrical connections to a motor, a shaft to drive the pump, a seal between the water chamber and the motor, an impeller with inlet and outlet ports, and a mounting stand. Rail systems are recommended when using large submersible pumps to access pumps for repair or replacement.

Bearings

Several types of bearings are used in pumps, such as ball bearings, roller bearings, and thrust bearings. Each bearing has a special purpose. The type of bearing used in each pump depends on the manufacturer's design and application.

Bearings are machine parts designed to reduce friction between moving parts or to support moving loads. There are two main kinds of bearings:

- Antifriction type, such as the roller bearing and ball bearing, operate on the principle of rolling friction.
- Plain or sliding type, such as the thrust bearing, employ the principle of sliding friction; thrust bearings are used to support the pump shaft.

Pump bearings should last for years if serviced properly and used in their proper application. Whenever a bearing failure occurs, the bearing should be examined to determine the cause and, if possible, eliminate the problem. Many bearings are ruined during installation or pump startup.

Packing

Pump packing reduces or eliminates internal liquid leakage within a pump. This is important because the objective is to pump water, not air, and because air leakage can cause a pump to lose suction. To keep air from being drawn into the pump, *stuffing boxes* are used. Each stuffing box consists of casing, rings of packing, and a gland at the outside end. Each ring of packing should be placed separately and seated firmly before adding the next. These rings are removable and replaceable when wear enlarges the tiny gap between them and the impeller.

In addition to increasing the efficiency of the pump by reducing air leakage, pump packing can prolong the life of the pump and shaft by reducing friction. The manufacturer's recommendations should be followed in choosing a packing.

Mechanical Seals

Many pumps use mechanical seals in place of packing. Mechanical seals serve the same purpose as packing: they prevent leakage between the pump casing and shaft. Like packing, they are located in the stuffing box where the shaft goes through the volute; however, they should not leak.

Mechanical seals have two faces that mate tightly and prevent water from passing through them. One half of the seal is mounted in the pump or gland with an "O" ring or gasket, thus providing sealing between the housing and seal face. This prevents water from going around the seal face and housing. The other half of the mechanical seal is installed on the pump shaft. This part also has an "O" ring or gasket between the shaft and seal to prevent water from leaking between the seal part and shaft. There is a spring located behind one of the seal parts, which applies pressure to hold the two faces of the seal together and keeps any water from leaking out. One half of the seal is stationary, and the other half is revolving with the shaft.

Some of the advantages of mechanical seals are as follows:

- They last from 3 to 4 years without maintenance, resulting in labor savings
- Usually no damage results to the shaft sleeve when the seals are replaced
- Continual adjusting, cleaning, or repacking is not required

Some of the limitations of mechanical seals include the following:

- High initial cost
- Competent mechanic required for installation
- When they fail, pump must be shut down
- Pump must be dismantled to repair

Lubrication

Pumps, motors, and drives should be oiled and greased in strict accordance with the recommendations of the manufacturer. The best quality oils and grease obtainable should be used. Overgreasing should be avoided, as too much grease will cause as much damage as lack of lubrication. It is especially important not to overlubricate motor bearings as this can lead to bearing seal failures. This has been the cause of an untold number of motor failures. The present trend is toward the increased use of sealed bearings that require no additional grease for their lifetime.

Priming a Pump

A pump will not operate unless it has been properly primed. A pump is considered primed when the pump casing and suction piping are completely filled with liquid. A pump that has a positive suction head will seldom lose its prime, whether the pump is on or off, and will likely only need to be primed after it has been opened or replaced.

For pumps with a negative suction head (suction lift), the water tends to run back out of the pump and down the suction line when the pump stops. If the casing is filled with air, the impeller cannot create enough vacuum upon starting to draw water back into the unit, and the air will just circulate around in the pump. In this situation, both the pump and motor will overheat in a short time. If a positive suction head cannot be provided, the pump must be separately primed (filled with water) each time it is started unless it is equipped with some type of self-priming device, such as a foot valve, a vacuum pump or ejector, or a priming chamber.

Cavitation

Cavitation is the formation and collapse of a gas pocket or bubble on the blade of an impeller. This condition results from unusually low pressures that can occur when pump inlet pressures drop below the design inlet pressures or when the pump is operated at flow rates considerably higher than design flows. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or valve with a hammer. Cavitation can also sound like rocks or gravel passing through the pump or valve. Damage caused by cavitation can be severe, resulting in replacement of the impeller or the impeller and volute.

Water Hammer

Also known as hydraulic shock, *water hammer* is an oscillation in pressure that results from a too rapid acceleration or retardation of flow, such as when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system as well as producing a noise that sounds like someone hammering on a pipe.

Surge tanks installed in the areas where water hammer is a problem can absorb some of the pressure.

Air release (sometimes called air relief) valves can also help minimize water hammer damage. These devices allow the release of air in the distribution network while the system is pressurizing. These valves are usually installed at high elevation points in a distribution network, as well as at the end of laterals and trunk lines where air might be forced to a dead end.

Pump Controls

A variety of controls are used to operate pumping systems. These controls are used to activate pumps, valves, water-level sensing devices, alarms, timers, counters, and meters. Controls are contained in protected enclosures, called *control panels*. Control panels can be *simplex* (control one pump), *duplex* (control two pumps), or *multiplex* (control more than two pumps). All control panels should have a ground rod and a *hand-off-automatic* (HOA) switch that allows the WWLA operator to override the control system and manually activate the pump. Panels should have visual and audible alarms and an alarm silence switch.

Water-Level Sensing and Pump Control

Accurate sensing of high and low water levels is critical for proper timing of pump operation. Control of pumping systems is achieved by an ON/OFF type of control, which starts and stops pumps according to a level, pressure, or flow measurement.

Usually an ON/OFF pump control system responds to level changes in a tank of some type. Water level can be sensed directly with a float or by a pressure change at the tank or pump site. The pump is thus turned off or on as the tank level rises above or falls below the predetermined level or pressure limits. These controls can either be single-point detection or continuous detection.

Other possible pump controls include turning the pump OFF if there is a loss of the level signal or low suction pressure.

Types of ON/OFF pump controls include the following:

- Float switches
- Pressure bulbs and diaphragm switches
- Bubble tubes
- Electrode switches
- Ultrasonic sensors

Appendix E. Pipes, Connections, and Valves

Pipes

Before discussing specific types of pipes, the following definitions and abbreviations apply:

- Outside diameter (OD).
- Inside diameter (ID).
- Iron pipe size (IPS). IPS is an old pipe size designation based on the inside diameter of the pipe. IPS is still in use by some pipe manufacturers today.
- Plastic irrigation pipe size (PIP). PIP pipe depending on the type of pipe (solvent weld, belled end, or gasketed joint) have the same OD with varying IDs.
- Class—Pipe's pressure rating (PR). PR is the standard pressure rating of the pipe. Typically for steel pipe, it is the flange rating, and for PVC pipe, it is the long-term pipe system rating (pipe and fittings).
- Standard dimensional ratio (SDR) number; SDR is defined as the outside diameter divided by the minimum wall thickness; the larger the SDR number, the thinner the pipe wall thickness.
- Nominal pipe thread (NPT). NPT is a standard for tapered pipe threads and is the measure of the rate of pipe thread taper or change in pipe thread diameter over a distance. The taper rate for all NPT threads is 1/16.

Piping used in land application systems can either be made of concrete, metal (iron, stainless steel, copper, aluminum) or plastic (polyvinyl chloride [PVC] or *polyethylene*). Several of these are discussed below:

Concrete—Concrete pipe is primarily used for large diameter lines. The most common type of concrete pipe is manufactured by wrapping a wire around a steel cylinder and using a cement coating to cover the steel cylinder both internally and externally. This pipe is made to withstand internal pressures up to 300 pounds per square inch (psi) and can be placed in trenches up to 70 feet deep. Concrete pipe is very resistant to corrosion except in very low pH waters. The cement mortar is the protective agent for the steel cylinder; therefore, the pipe must be handled with care. Damage to the cement mortar either internally or externally will subject the pipe to corrosion. Advantages of this material are its ability to withstand high external loads and corrosion. Major disadvantages are its weight and the care with which it must be installed.

Cast Iron—Cast iron pipe is some of the oldest piping material in use today. It is now manufactured by a process called *spin casting*, during which molten iron is injected into a spinning mold. The result is a pipe of consistent diameter and wall thickness. Cast iron pipe can withstand high working pressures. Pressure ratings of 350 psi are common. However, the material cannot withstand sharp shock loads either internally or externally.

Steel—Steel pipe is made by extruding or welding sections of steel to form a pipe. This pipe falls into two categories: *mill pipe* and *fabricated pipe*. Steel pipe is classed as a flexible conduit, meaning that it has the ability to withstand a 3% deflection of the diameter without damage to the pipe. Steel pipe is commonly manufactured to meet very high pressures (up to 700 psi is not uncommon). However, under a vacuum it will collapse. Because steel pipe is a flexible conduit, it requires a selection of wall thickness suitable to withstand external loads as well as internal loads. Steel can easily be shaped into various sizes and shapes, which is one of its major advantages. It also has a high tensile strength and high ductility. These characteristics give it the ability to withstand high internal and external loads. The main disadvantage of steel pipe is that it is easily attacked by corrosive elements, which results in high maintenance costs. An additional disadvantage is that it will collapse under a vacuum. Epoxy coated steel is more resistant to corrosion and offers longer life spans.

Cement asbestos—Cement asbestos (or AC pipe) is made from Portland cement, long fiber asbestos, and silica sand. The pipe is formed on a spinning anvil and cured in an autoclave. Three common classes of pipe are made: Class 100, 150, and 200. These classes refer to the working pressure rating of the pipe. AC pipe is easily corroded and has high hydraulic capabilities and a low shear strength. It is easily damaged by shock loads, either internally or externally.

Aluminum—Aluminum pipe is used in aboveground situations as portable pipe. It is often used to pipe water to a traveling irrigation device, such as a center pivot tower or traveling gun hose-reel. Aluminum pipe is sometimes used in solid set systems as well. It is lightweight, very portable, and easily connected. Aluminum pipe does not offer good strength and is easily damaged by machinery or fallen trees. Often, leaks can occur until the distribution system is fully pressurized. Aboveground aluminum pipe is not suitable where winter operation is necessary, as freezing causes pipe damage as well as poor function of the sprinkler heads attached to the pipe due to ice clogging.

Ductile Cast Iron Pipe (DIP)—Ductile cast iron pipe is made by injecting magnesium into the cast iron during the molding process. The magnesium alters the shape of the carbon structure of the cast iron, giving the pipe superior beam strength. It will resist high impacts and is more corrosion resistant than gray cast iron. Ductile iron pipe is classed by wall thickness. The common thickness class ranges from 50 through 56; the higher the number, the thicker the wall. However, wall thickness also varies with the size of the pipe. The thickness class needed for a particular condition is based on the internal working pressure, depth of the cover, pipe size, and type of bedding condition to be used. Because of its ability to withstand high stress, extreme beam and crush loads, unusual shock, unstable bedding and deep fills, ductile cast iron pipe is one of the few materials that can be used in extreme conditions. Its disadvantages are its weight and its susceptibility of corrosion.

PVC—PVC pipe is made from unplasticized polyvinyl chloride. This material only gained wide acceptance in the water industry when a thicker walled material was developed and an acceptable standard was adopted. The standard that governs most of this thick-walled PVC pipe is called C-900. This distinguishes it from other PVC pipe that has a thinner wall. PVC is manufactured in various sizes and wall thicknesses.

Three groupings of pipe material are commonly used in the water industry.

Scheduled Pipe—First there is the *scheduled* pipe. *Schedule* refers to the thickness of the pipe; a higher number denotes a thicker pipe. The two common schedules are schedule 40 and schedule 80. This material is not normally placed in a trench but is used as piping in small pump stations and in chlorine stations. The wall thickness, ID, and OD of scheduled pipe are based on steel pipe dimensions. The working pressure will vary from 600 psi for 1/2-inch schedule 40 to 160 psi for 8-inch schedule 40.

Pressure Pipe—Second there is what is called *pressure pipe*. This material is manufactured in iron pipe OD sizes (IPS). The common classifications of this pipe are 160 psi, 200 psi, and 315 psi. This material can be joined by either push-on gasket fittings or solvent welds.

Class Pipe—Third, there is *class pipe,* which is manufactured in both iron pipe OD sizes and cast iron OD sizes. The three classes of this material are based on a standard working pressure. The classes are 100, 150, and 200. The wall thickness of the pipe increases as the pipe diameter increases. Class 200 PVC pipe with cast iron pipe outside dimensions is the most common class pipe used in the wastewater industry.

The primary advantages of PVC pipe are its light weight, the ease with which it can be cut, and its ability to resist corrosion. One of its disadvantages is its inability to withstand high impact and shocks. It is also sensitive to sunlight if stored outside too long and will elongate in high ambient temperatures, making installation difficult. Plastic pipe should not be used in areas where petroleum products may be present. Finally, in cold weather it becomes brittle, requiring special handling.

Connections

A connection is a collar or coupling that fits over adjacent ends of pipe to be joined, and which, when drawn tight, holds the pipe together either by friction or by mechanical bond. Connections include the following:

- Flange—A connection made by flanges bolted together; the joint is made water-tight by a gasket placed between the two flanges.
- Mechanical joint—Any form of flexible joint involving lugs and bolts; uses a bell and spigot arrangement. A rubber gasket is placed around the spigot. The gasket is forced into the bell by a metal ring (called a follower ring) that is held to the bell by a series of bolts.
- Bell and spigot—A form of joint used on pipes with an enlarged diameter or bell at one end and a spigot at the other, which fits into and is laid in the bell. The joint is then made tight by lead, cement, rubber O-ring, or other jointing compounds or materials.
- Threaded—A connection made by threading a male end section of pipe or fitting into a female fitting or adapter. With metal threads, pipe compound is typically required for a waterproof seal. Teflon thread tape may be used on metal or PVC pipe threads.
- PVC cement—Also called "solvent weld"; uses a special primer and glue to physically mate (connect) pipe and fittings. The glue causes the PVC to bond by a chemical reaction that melts the two pipes, allows them to combine, then cools and solidifies into the banded pipe.

Valves

A valve is a device installed in a pipeline to control the magnitude and direction of the flow. It consists essentially of a shell and a disk or plug fitted to the shell. Valves vary in construction and size, depending upon their function. Some are classified according to their method of operation or design and some are named for the functions they perform. Valves can be operated automatically or manually. Types of valves encountered in a land application system include the following:

- Gate valve—Typically used as a shut-off valve. A disc in the valve is raised and lowered by a threaded stem or sliding stem to open and close the valve. Gate valves are used in pressure distribution systems to regulate the rate of water flow. Gate valves are designed to operate fully open or fully closed.
- Plug valve—Often used in multiple outlet valves, such as diversion valves. Like a gate valve, a plug valve has an unobstructed flow, yet requires only a 90^o turn to open it. The movable control element is a cylindrical or conical plug, in contrast to a flat disk. The valve is turned directly with a key to change the less-than-fully open port.
- Butterfly valve—Has a disc that turns sideways to open the valve. It is a one-quarter turn valve and can be used for throttling relatively clean water. The disk, as it opens or closes, rotates about a spindle supported by the frame of the valve. The valve is opened at a stem. At full opening, the disk is in a position parallel to the axis of the conduit.
- Check valve—Allows water to flow in only one direction. Check valves either have ball or flapper mechanisms that prevent backflow. Check valves consist of a valve provided with a disk hinged on one edge so that it opens in the direction of normal flow and closes with reversal of flow.
- Solenoid valve—Uses a solenoid (an electric coil) to open and close small openings to divert fluid from one side of a diaphragm to the other. When the pressure on top of the diaphragm is equal to the inlet pressure, the valve will remain closed. When pressure is released from on top of the diaphragm, a pump can then open the device. Solenoids can operate small valves or other electrical switches.
- Pressure relief valve—Valve that, when actuated by static pressure above a predetermined level, opens in proportion to the excess above this level and reduces the pressure.
- Air relief valve—Designed to allow the release of air pressure in an irrigation system. Air relief valves are typically installed at the distal ends of long runs of piping, at high elevation points in fields, and at other places where air may be trapped, such as at a field valve or sharp turn in the piping. These valves have a ball or some mechanism that allows air to escape but shuts tightly when water pressure enters them. Their purpose is to allow air that is in the piping system to escape when water is being pumped into the system and to help eliminate damage to pipes and sprinklers from excessive air pressure.
- Globe valve—Is directed through the valve in a specific direction, then is forced to change direction and go through a large orifice, hit a disk and again change direction to exit the valve. This induces head loss and makes it a good throttling device. It has a round, ball-like shell and horizontal disk.
- Bleeder valve—Used for draining a tank, tube, etc.

Appendix F. Soil Sampling

The following document on soil sampling can also be found at *http://www.cals.uidaho.edu/edComm/pdf/EXT/EXT0704.pdf.*

Soil Sampling

Bulletin 704 (revised)

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College of Agriculture

University of Idaho Cooperative Extension System

Soil Sampling

Environmental concerns have brought nutrient management in agriculture under increased scrutiny. A goal of sound nutrient management is to maximize the proportion of applied nutrients that is used by the crop (nutrient use efficiency). Soil sampling is a best management practice (BMP) for fertilizer management that will help improve nutrient use efficiency and protect the environment.

Soil sampling is also one of the most important steps in a sound crop fertilization program. Poor soil sampling procedures account for more than 90 percent of all errors in fertilizer recommendations based on soil tests. Soil test results are only as good as the soil sample. Once you take a good sample, you must also handle it properly for it to remain a good sample.

A good soil testing program can be divided into four operations: (1) taking the sample, (2) analyzing the sample, (3) interpreting the sample analyses, and (4) making the fertilizer recommendations. This publication focuses on the first step, collecting the soil sample.

Once you take a sample, you must send it to a laboratory for analysis. Then the Extension agricultural educator or fertilizer fieldman in your county can interpret the analysis and make specific fertilizer recommendations. Fertilizer guides from the University of Idaho Cooperative Extension System are also available to help you select the correct fertilizer application rate.

The soil sampling guidelines in this publication meet sampling standards suggested by federal, state, and local nutrient management programs in Idaho.

What is a soil test?

A soil test is a chemical evaluation of the nutrient-supplying capability of a soil at the time of sampling. Not all soil-testing methods are alike nor are all fertilizer recommendations based on those soil tests equally reliable.

Reliable fertilizer recommendations are developed through research by calibrating laboratory soil test values and correlating them with crop responses to fertilizer rates. These soil test correlation trials must be conducted for several years on a particular crop growing on a specific soil type. If soil test calibration is incomplete, fertilizer recommendations based on soil-test results still can only be best guesses.

A soil test does not measure the total amount of a specific nutrient in the soil. There is usually little relationship between the total amount of a nutrient in the soil and the amount of a nutrient that plants can obtain.

A soil test also does not measure the amount of plant-available nutrients in the soil because not all the nutrients in the soil are in a form readily usable by plants. Through research, however, a relationship can usually be established between soil test nutrient levels and the total amount of a nutrient in the soil.

What does a soil test measure?

Present soil-testing methods measure a certain portion of the total nutrient content of the soil. During testing, this portion is removed from the soil by an extracting solution that is mixed with the soil for a given length of time. The solution containing the extracted portion of the nutrient is separated from the soil by filtration, and then the solution is analyzed.

A low soil-test value for a particular nutrient means the crop will be unable to obtain enough of that nutrient from the soil to produce the highest yield under average soil and climatic conditions. A nutrient deficiency should be corrected by adding the nutrient as a fertilizer. The amount of nutrient that needs to be added for a given soil-test value is calculated based on results from the correlation research test plots.

Sampling timing

Because nutrient concentrations in the soil vary with the season, you should take soil samples as close as possible to planting or to the time of crop need for the nutrient. Ideally, take the soil samples 2 to 4 weeks before planting or fertilizing the crop. It usually requires 1 to 3 weeks to take a soil sample, get the sample to the testing laboratory, and obtain results.

Sampling very wet, very dry, or frozen soils will not affect soil test results though collecting soil samples under these conditions is difficult. Do not sample snow–covered fields. The snow makes it difficult to recognize and avoid unusual areas in the field, so you may not get a representative sample.

Sampling frequency

For best soil fertility management, especially for the mobile nutrients, sample each year and fertilize for the potential yield of the intended crop. Having an analysis performed for every nutrient each year is not necessary. Whether you need an analysis of a nutrient depends on such things as its mobility in the soil and the nutrient requirements of the crop.

Take soil samples at least once during each crop rotation cycle. Maintain a record of soil test results on each field to evaluate long-term trends in nutrient levels.

Sampling procedure

One of the most important steps in a soil testing program is to collect a soil sample that represents the area to be fertilized. If the soil sample is not representative, the test results and recommendations can be misleading.

The correct steps in soil sampling are illustrated in figure 1. Before sampling, obtain necessary information, materials, and equipment from the Extension agricultural educator or fertilizer fieldman in your county.

Use proper soil sampling tools. A soil auger or probe is most convenient, but you can use a shovel or spade for shallow samples. You will need a plastic bucket or other container for each sample to help you collect and mix a composite sample.

Be sure that all equipment is clean, and especially be sure it is free of fertilizer. Even a small amount of fertilizer dust can result in a highly erroneous analysis. Do not use a galvanized bucket when analyzing for zinc (Zn) or a rusty shovel or bucket when analyzing for iron (Fe). If the sample will be analyzed for Fe or manganese (Mn), do not dry the soil sample before shipping.

When sampling, avoid unusual areas such as eroded sections, dead furrows, and fence lines. If the field to be sampled covers a large area with

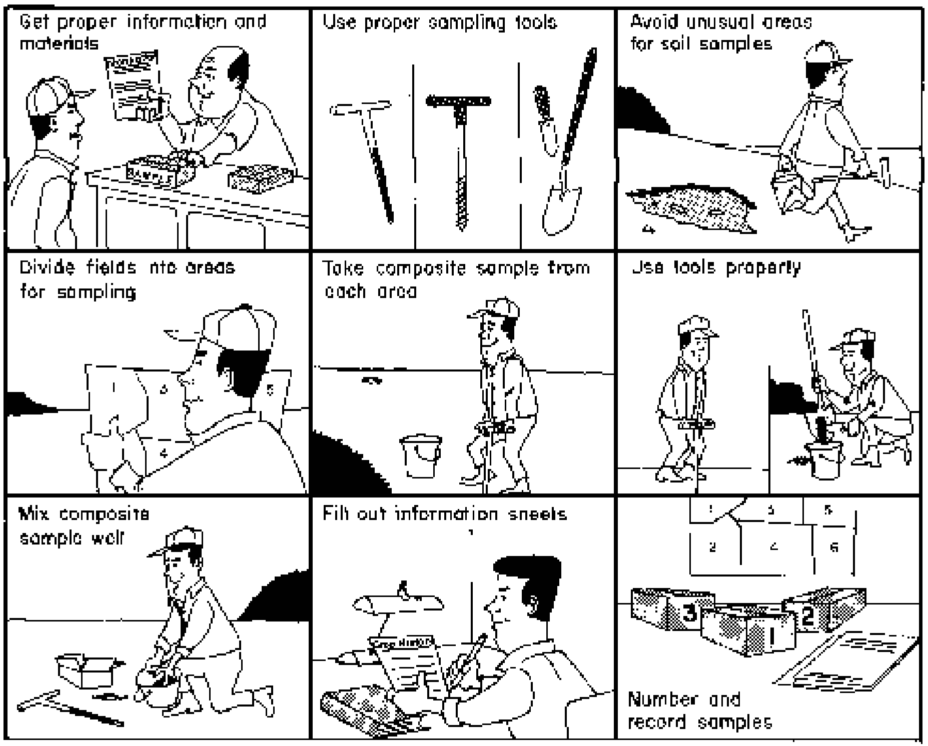

Fig. 1. Follow these steps to obtain a good sample for testing (redrawn courtesy of the National Fertilizer Institute).

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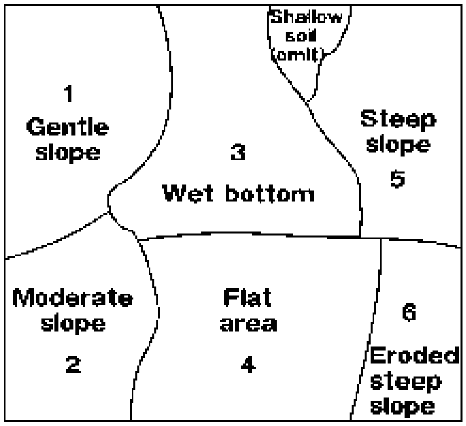

Fig. 2. A field with areas identified as sampling units.

Table 2. Effective rooting depth for some common Idaho crops.

Crop	Depth (feet)
Cereals (wheat, barley, oats)	5 to 6
Corn	5 to 6
Alfalfa, rapeseed	4 to 5
Hops, grapes, tree fruits	4 to 5
Sugarbeets	2 to 3
Peas, beans, lentils, onions, potatoes, mint	2
Vegetable seed	1 to 1 1/2

varied topography, subdivide it into relatively uniform sampling units (fig. 2). Sampling subdivision units that are too small to fertilize separately may be of interest, but impractical if you do not treat the small units differently from the rest of the field. Omit these areas from the sampling.

Within each sampling unit take soil samples from several different locations and mix these subsamples into one composite sample. The number of subsamples needed to obtain a representative composite sample depends on the uniformity and size of the sampling unit (table 1). Although the numbers of subsamples in table 1 give the best results, they may be unrealistic if you plan to take a great number of samples. An absolute minimum of 10 subsamples from each sampling unit is necessary to obtain an acceptable sample. The more subsamples you take, the better the representation of the area sampled.

Table 1. Number of subsamples recommended for a representative composite sample based on field size.

Field size (acres)	Number of subsamples
fewer than 5	15
5 to 10	18
10 to 25	20
25 to 50	25
more than 50	30

Take all subsamples randomly from the sampling unit, but be sure to distribute subsample sites throughout the sampling unit. Meander or zig-zag throughout each sampling unit to sample the area. Special considerations are necessary in eroded areas, furrow irrigation, under no-till, and where fertilizer is banded (see "Special Sampling").

The total amount of soil you collect from the sampling unit may be more than you need for analyses. Mix the individual subsamples together thoroughly and take the soil sample from the composite mixture. The composite sample should be at least 1 pint—about 1 pound—in size.

Sampling depth

Depth of sampling is critical because tillage and nutrient mobility in the soil can greatly influence nutrient levels in different soil zones (fig. 3). Sampling depth depends on the crop, cultural practices, tillage depth, and the nutrients to be analyzed.

Because the greatest abundance of plant roots, greatest biological activity,

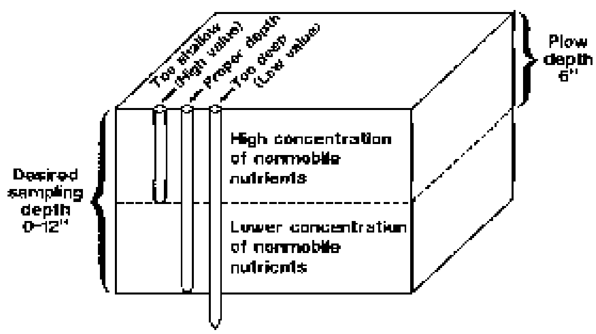

Fig. 3. Too deep or shallow a sampling depth can produce inaccurate soil test results. The plow layer is usually higher in nonmobile nutrients than the soil layers below it.

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and highest nutrient levels occur in the surface layers, the upper 12 inches of soil are used for most analyses. The analyses run on the surface sample include soil reaction (pH), phosphorus (P), potassium (K), organic matter, sulfur (S), boron (B), zinc (Zn), and other micronutrients.

Sampling depth is especially critical for nonmobile nutrients such as P and K. The recommended sampling depth for nonmobile nutrients is 12 inches (fig. 3).

The tillage zone, typically 6 to 8 inches deep, usually contains a relatively uniform, high concentration of nonmobile nutrients. Below the tillage zone the concentration is usually lower. Therefore, a sample from the tillage zone will usually have a higher content of nonmobile nutrients than a sample from the desired 0- to 12-inch sample depth. This can lead to erroneous results.

Depth sampling

When sampling for mobile nutrients such as nitrogen (N), boron (B), and sulfur (S), take samples by 1-foot increments to the effective rooting depth of the crop (fig. 4). This can be a depth of 5 to 6 feet (table 2) unless the soil has a root-limiting layer such as bedrock or hardpan. For each foot depth, take 10 or more subsamples at random from the sampling unit.

If you plan to sample less than a year after banding or injecting fertilizer or if you have any question about fertilizer placement, use the sampling technique described under "Areas Where Fertilizer Has Been Banded." Irrigation or precipitation should disperse mobile nutrients over a period of a year.

Sample handling

Soil samples need special handling to ensure accurate results and minimize changes in nutrient levels because of biological activity. Keep moist soil samples cool at all times during and after sampling. Samples can be frozen or refrigerated for extended periods of time without adverse effects.

If the samples cannot be refrigerated or frozen soon after collection, air dry them or take them directly to the soil testing laboratory. Air dry by spreading the sample in a thin layer on a plastic sheet. Break up all clods or lumps, and spread the soil in a layer about 1/4 inch deep. Dry at room temperature. If a circulating fan is available, position it to move the air over the sample for rapid drying.

Caution: Do not dry where agricultural chemical or fertilizer fumes or dust will come in contact with the samples. Do not use artificial heat in drying. Ask the Extension agricultural educator or fertilizer fieldman in your county for more details concerning special handling of soil samples.

When the soil samples are dry, mix the soil thoroughly, crushing any coarse lumps. Take from the sample about 1 pint (roughly 1 pound) of well-mixed soil and place it in a soil sample bag or other container. Soil sample bags and soil test report forms are available from the Cooperative Extension System office in your county or from a fertilizer fieldman.

Label the bag carefully with your name, the sample number, sample depth, and field number. The field number should correspond with a field or farm map showing the areas

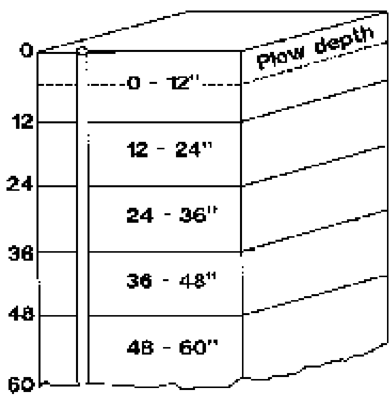

Fig. 4. Depth sampling (successive samples by 12-inch increments) for mobile nutrients (especially N) should be continued to rooting depth, which may be 5 to 6 feet for some crops.

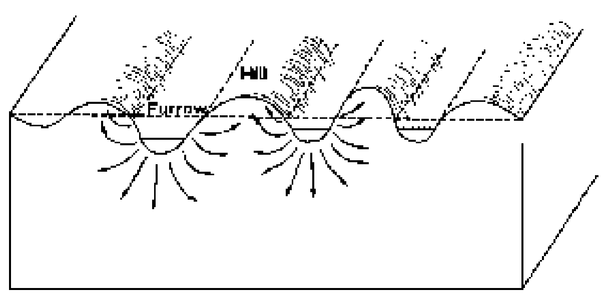

Fig. 5. Movement of mobile nutrients in furrow-irrigated fields.

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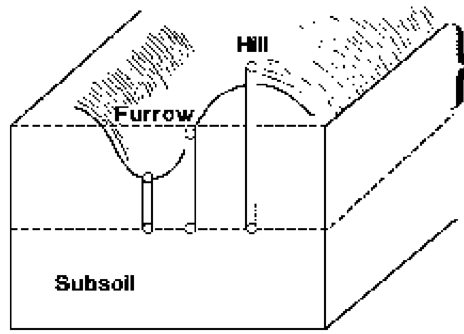

Fig. 6. Special sampling techniques are required when soil sampling furrow-irrigated fields. Take a sample from the hilltop, the furrow bottom, and at the midpoint between the hilltop and furrow bottom. The 12-inch sampling depth is based on the midpoint sampling location.

sampled. This will help you keep an accurate record of soil test reports. Provide information on crop to be grown, yield potential, recent history of crops grown, yields, fertilizer applied, and other information.

Sample analysis

Analyze regularly only for those nutrients that have been shown to be yield limiting in your area or for the crop to be grown. In general, all soils should be analyzed for N, P, K, and S . For determination of potential need for micronutrients, refer to PNW 276, *Current Nutrient Status of Soils in Idaho, Oregon, and Washington.* Occasional analyses for micronutrient concentrations may be advisable.

Special sampling

Special sampling problems occur in fields that have been leveled for irrigation, fields that have lost all or most topsoil as a result of erosion, fields that are surface (furrow) irrigated, fields that have had a fertilizer band applied, and fields that are not thoroughly tilled.

Land-leveled and eroded areas

Areas that have been eroded or artificially leveled for irrigation usually have little or no original topsoil. The soil surface may be exposed subsoil material. These areas should be sampled separately if they are large enough to be managed differently from where topsoil has not been removed. Subsoil material is usually low in organic matter and can be high in clay, calcium carbonate (lime), or both.

Furrow-irrigated fields

For a representative soil sample, sample furrow-irrigated fields before the furrowing operation. If furrowing has already been completed, follow the special sampling procedures described here.

The movement of water and dissolved plant nutrients can create unique nutrient distribution patterns in the hills between the furrows (fig. 5). To obtain a representative sample, you need to be aware of furrow direction, spacing, and location, and to take closely spaced soil samples perpendicular to the furrow (fig. 6).

Approximately 20 sites (with at least three samples per site) are needed for a representative composite soil sample. At each sampling site, take a sample from the hilltop, from the midpoint between the hilltop and furrow, and from the furrow bottom. The sampling depth at the midpoint between the hilltop and furrow bottom should be 12 inches. The bottom point of this sample should be the same as for the furrow and hilltop samples. Thus, the furrow sampling depth will be less than 12 inches, while the hilltop sampling depth will be more than 12 inches (fig. 6).

Mix the hilltop, midpoint, and furrow samples to make a composite sample for each site. Mix the site samples for a representative composite field soil

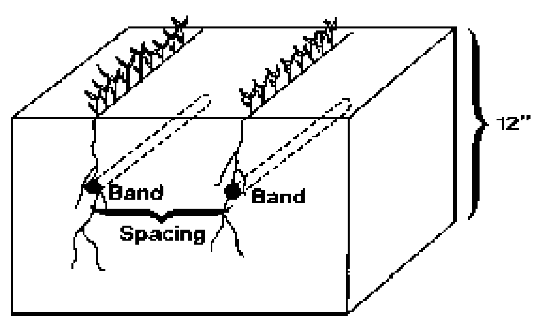

Fig 7. Diagram of fertilizer location in soil where fertilizer has been banded.

sample to be analyzed for nonmobile nutrients (P, K, and micronutrients). Deeper profile sampling (depth sampling) is recommended for mobile nutrients (N and S).

Areas where fertilizer has been banded

Banding of fertilizers is becoming a more common practice (fig. 7). In fields where fertilizers have been banded and tillage has occurred before soil sampling, regular sampling procedures can be followed. However, if tillage has not adequately mixed the soil, special soil sampling is required. If a field has had a banded fertilizer application the previous growing season and has not been plowed, an ideal sample would be a continuous slice 1 to 2 inches thick and 12 inches deep extending from the center of one band to the center of the next band.

Little research has been conducted to determine the best method of sampling banded fields. Currently three different approaches are used widely. Each method produces a satisfactory representative sample, but the effort required to obtain these samples differs considerably.

Systematic sampling method. If you know the direction, depth, and spacing of the fertilizer band, you can obtain a representative soil sample with this sampling procedure. Take 5 to 10 soil samples perpendicular to the band row beginning in the edge of a fertilizer band and ending at the edge of an adjacent band (fig. 8). Follow this procedure on at least 20 sampling sites in each field or portion of a field being sampled. Mix and composite the soils collected from each site to obtain a representative soil sample.

Controlled sampling method. You also should know the direction, depth, and spacing of the fertilizer bands to obtain a representative soil sample with this method. Take 20 to 30 soil cores from locations scattered throughout the field or portion of the field. Avoid sampling directly in a fertilizer band.

The composite sample should adequately represent the area being sampled. This method may result in slightly lower soil test values of nonmobile nutrients (P, K, and micronutrients) than the systematic and random sampling methods.

Random sampling method. Use this sampling method when the location of the previous season's fertilizer bands is not known. Take 40 to 60 random soil cores to form a composite sample of the area being sampled.

Reduced tillage or no-till fields

You may need special approaches to soil sampling with reduced tillage or no-till fields because the soil has been disturbed so little that fertilizer, whether broadcast on the surface or banded below the surface, is not mixed into the soil. You need to know the history of fertilization, tillage, and other management practices to determine how to obtain a representative sample.

If nonmobile nutrients (P, K, and micronutrients other than B) have been surface broadcast and little or no tillage has been used since their application, remove the surface 1 inch of soil before sampling. Nutrients in the top inch of soil will probably not be available to the growing crop.

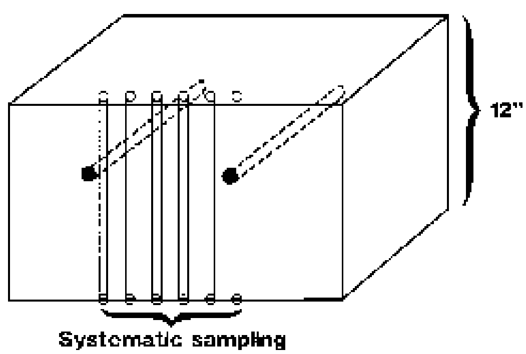

Fig. 8. Systematic soil sampling in a field where fertilizer has been banded (sampling method 1).

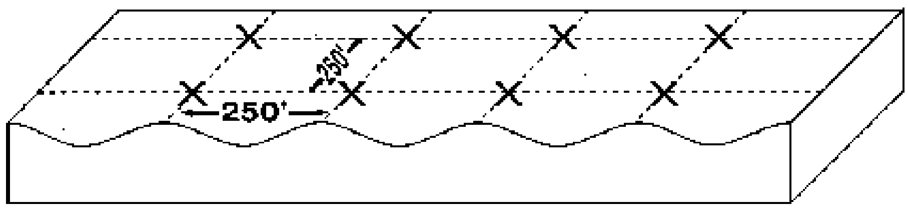

Fig. 9. Grid soil sampling pattern where samples are collected every 250 feet. Note that a complete soil sample is collected at each spot marked with an X.

If fertilizer has been banded with the no-till system, consider methods suggested in "Areas Where Fertilizer Has Been Banded." If a field has been under a continuous no-till system for a long time, determine the pH of the surface foot at 3-inch intervals (0 to 3, 3 to 6, 6 to 9, 9 to 12 inches) every 3 to 5 years. Soil pH will affect the availability of fertilizer nutrients as well as the activity of commonly used herbicides, insecticides, and fungicides.

Grid sampling in nonuniform fields

Many fields are not uniform and vary both horizontally and vertically across landscapes. Traditional soil sampling procedures average nutrient levels in soil subsamples to determine average nutrient levels in the field. The nutrient values obtained are good, but the manager must realize that many of the values in the field are either less than or greater than the values determined. When fields are broken into grids with shorter distances between the sampling points a more precise soil map can be developed to determine nutrient needs.

The technology is now available to combine grid sampling with variable rate fertilizer application to handle spatial variability within a field. These application techniques make fertilizer nutrient application more precise, resulting in greater nutrient use efficiency and reducing pollution potential.

Irrigated fields including individual pivots should be set up in a 200- to 300-foot grid for potato, sugarbeets, corn, and other potentially high-N-use crops (fig. 9). A wider grid of 400 feet may be used for small grains, beans, and other crops where N management is less intensive or under dryland conditions.

Soil nutrient needs for each segment of the grid are entered into a computer-driven system mounted on specialized commercial fertilizer application equipment. Variable rates of nutrients are then applied based on individual soil samples over the entire field.

A similar system designed for fertilizer applications through pivot sprinklers is being developed by the University of Idaho. This system has the potential to apply variable rates of nutrients and water specifically related to changes across individual fields.

The Soil Conservation Service has a digitized soil survey information system (SSIS), which when combined with the results of grid sampling provides specific information and recommendations for soils and soil types within a field. The SSIS can locate pockets of sandy or coarse-textured soils where leaching is a major concern or areas of finer-textured soils where pockets of residual N may occur. The SSIS also indicates where erosion or surface runoff may be high and where areas should be targeted for federal programs such as the Conservation Reserve Program.

Another computer-mapping technique, Geographic Information Systems (GIS), can be combined with the results of grid sampling to provide growers and land managers with information for land-use planning.

Additional information on proper soil sampling procedures can be obtained from the Extension agricultural educator or fertilizer fieldman in your county.

The authors—Robert L. Mahler, soil scientist, Moscow, and Terry A. Tindall, former Extension soil scientist, Twin Falls Research and Extension Center; both with the University of Idaho Department of Plant, Soil, and Entomological Sciences.

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Appendix G. Plant Tissue Sampling

The following is an excerpt from the *Guidance for Land Application of Municipal and Industrial Wastewater*, which can be accessed in its entirety at *http://www.deq.idaho.gov/media/516329-guidance_reuse_0907.pdf.*

7.6.5.1 Sampling

Only the plant parts that are removed from the site need be sampled. In the case of a hay crop, the entire plant top is cut and removed, so the entire plant should be sampled. In the case of small grains, if the grain and stover (above-ground plant parts excluding the seed) are both harvested and removed, both should be sampled. If the stover is left on site, then only the grain should be sampled.

CES (1997) outlines plant tissue sampling methods, which are summarized here. Plant tissue samples of green, growing crops such as forages should be taken immediately prior to harvest. Sampling forage crops immediately prior to harvest can result in 10 to 20 percent higher nitrogen levels because of plant tissue degradation following harvest. Samples should be collected to be representative of the crop at the time of harvest or just prior to harvest. Sampling of small areas of the field where plants are under severe moisture or temperature stress is not recommended. Plants that are dust covered, mechanically injured, diseased, or dead should not be sampled (Walsh and Beaton, 1973). The exception to this is when mechanical injury, disease or crop death is representative of the material being harvested. Crop tissue should be tested in these cases.

Samples should be collected at random locations in the hydraulic management unit. Specific crop types require particular sampling methods. For harvested grain, bean, silage or green chop, one grab sample from each day of harvest should be collected. They should be placed in paper bag and refrigerate, then mixed and a composite sample (1 liter wet or ½ liter dry) sent to the laboratory. For bailed hay, collect three composite samples from each harvest from each field. Each hay sample should be composited from at least ten cores from the ends of randomly selected bales. Then mix and send to the laboratory.

Potatoes require special sampling methods due to their size and the presence of two harvested plant parts, namely the potato and the vines. Collect on grab sample per day during harvest consisting of at least five potatoes. Quarter each potato and discard three of the quarters. Retain one quarter from each potato for a daily grab sample. Keep subsamples refrigerated and send all quarters to the laboratory for analysis. If the potato vines are to be burned, vine yield and nutrient (nitrogen only) uptake by the vines should be measured. Collect the vines from three four-foot sections of row in four locations in each hydraulic management unit (CES, 1997). Then reduce the sample size by splitting the pile of collected vines prior to shipping to the laboratory. Refrigerate after sampling and send at least 1 liter, but preferably one gallon, of volume of sample to the laboratory.

For forage crops, each sample should consist of the clippings from a minimum ten square feet of area. A square wooden frame or a wire whoop placed on the forage is effective to delineate the area to be sampled. The frame should be randomly dropped along a transect or grid pattern. The plants should be clipped within the frame at the same level that would result from the mechanical harvesting equipment. Hand operated or other clippers may be used.

Place each composite sample in a large paper bag so the sample can ‘breath’ (some sources recommend a perforated plastic bag). Put the sample in a cool place and deliver to the laboratory within two hours (CES, 1997). Ship or store samples in a chilled cooler if delivery in two hours cannot be accomplished. Delivery within 24 to 48 hours is acceptable if samples are kept dry and chilled in ‘breathable bags. Illinois (No Date) recommends a quick washing of plant tissue in a 0.1 – 0.3 percent non-phosphate containing detergent accompanied by three rinses in de-ionized water, in order to remove any dust, fertilizer, pesticide or other residues from the leaf surfaces.

As an alternative to collecting and transporting fresh plant tissue samples to the laboratory within short time-frames, samples may be dried in a clean muslin bag or tray inside a forced draft oven at 65 C for 48 hours. Tissue samples may then be ground after drying and placed in a bottle and allowed to dry for an additional 24 hours at 65 C. After this, samples are ready for analyses (Illinois, No Date). Walsh and Beaton (1973) may be consulted for further information regarding plant tissue sampling and analyses.

Appendix H. Ground Water

Equipment and Supplies for Sampling Ground Water

Prior planning and careful preparation of field equipment before sampling will ensure good results from the laboratory. The following is a list of supplies and equipment to be used when sampling ground water:

- Disposable gloves
- Documentation (forms, log books, and operations and maintenance [O&M] manual)
- Indelible ink pen
- Well lock keys
- Tape measure
- Water level monitoring device and supplies (batteries, chalk, and paste as needed)
- Field parameter meters with calibration standards
- Decontaminated sampling pump with proper tubing and power supply
- Bailers with line
- Sample bottles
- Sample labels
- Packing tape
- Stop watch
- Graduated cylinder
- Filtration equipment
- Cooler with cold packs or ice
- Cleaning buckets and containers
- Plastic garbage bags
- Small sealable plastic bags or containers
- Plastic sheeting
- Paper towels and hand soap
- Cleaning brushes
- Phosphate-free laboratory soap
- Deionized organic-free water and hand sprayers
- High purity laboratory grade hexane, acetone, or isopropanol (all available from laboratory supply companies)

Customized kits for sample collection may be supplied by the laboratory. These kits include all the items needed for collection and shipment of samples. Follow laboratory instructions and read container labels. Be careful not to discard preservatives that may have already been added to some containers.

If not using a kit, use only new containers or sanitized reusable containers, supplied by a lab, of the appropriate types for the required parameters. Select and prepare them according to the laboratory's instructions. Label sample containers before sample collection and record the type and amount of preservative required on each sample label. Ensure that all sampling equipment, such as bailers, containers, and tubing has been selected and thoroughly cleaned based on the parameters to be monitored. Disposable bailers of the appropriate composition may be used. Use Teflon, stainless steel, or glass when sampling for organics, such as solvents and petroleum product contamination. Do not use PVC or other plastics.

Measuring Static Water Level and Calculating Well Volume

To measure static water level, do the following:

1. From a permanent reference at the top of the well casing, lower a clean weighted steel tape or electric sounder into the well.
2. Record the wet level mark on the tape and subtract it from the reference point to obtain the depth of water. (Use the same reference point each time a water level measurement is made at the well.)

To calculate the well volume, do the following:

1. Subtract the depth to water level measurement from the known total depth of the well to obtain the height of the water column.
2. Calculate well volume in gallons by multiplying the inside area of the well (measured in square feet) times the height of the water column (measured in feet) times 7.48 gallons per cubic foot. Or use Table 1 for a quick conversion of well volume in gallons.

Table 1. Well diameter conversion.

Well Casing Diameter (inches)	Gallons per foot of Water Column Height
2	0.163
4	0.652
6	1.5
8	2.6

Special Handling Procedures

Certain types of sampling require special handling procedures:

- For trace metal analysis, use extra care in selecting and cleaning all sampling equipment, including pumps, bailers, and sample containers.
- For collecting volatiles, use stainless steel or Teflon bailers, if using a pump for sample collection that has a flow rate that cannot be adjusted to less than 100 milliliter per minute, and do the following:
  1. Collect duplicate samples for volatile organics in special 40-milliliter septum vials, with Teflon-lined disks in the caps to prevent contamination.

  2. Fill the vials to capacity, with no headspace, to prevent volatilization.

  3. Carefully pour the sample down the inside of the vials to minimize aeration and agitation until the containers are overflowing.

  4. Ensure that no air bubbles are trapped in the vials by applying the caps so that some overflow is lost.

5. If bubbles are noted when the vials are inverted and tapped, set those aside to be discarded.
6. Repeat the collection procedure using new vials. Include a trip blank of organics-free water, which must be obtained from the laboratory with each cooler containing samples collected for volatile organics.

- For coliform samples, collect directly into sterilized glass or sterilized plastic bottles that have been kept closed until ready to be filled. The sterilized containers often contain a preservative. Do not rinse prior to filling. Hold the bottles near the base until filled. Recap the bottles immediately, using care not to contaminate the bottles or lids. Store as required.

Filtering Samples

Adhere to the following requirements when filtering samples:

- Do not filter samples for coliforms.
- If there is a special request for the collection of a filtered sample for any analysis, use the appropriate type of filtering apparatus and filters.
- In low yielding wells and those containing high levels of suspended solids, lowering a bailer to below the static water level and allowing the well to recover into the bailer should produce a cleaner sample.
- Use purging and sampling techniques previously described to minimize agitation of sediment in affected wells and reduce the need for filtering. A pump used for purging and sampling will produce better samples from such wells.

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Appendix I. Winterization and Maintenance of Equipment

Winterization and Maintenance of Sprinkler Irrigation Equipment

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An irrigation system is an expensive investment. Regular maintenance and following recommended off-season storage procedures will help keep your system operating properly for many years. Following these procedures also reduces the risk of equipment failures that may lead to lost production time or crop loss. These procedures are particularly critical in wastewater application systems, where equipment failures could result in a discharge of liquid wastes and damage to the environment.

This publication provides general checklists for routine equipment inspections, regular maintenance schedules and winterization procedures for surface irrigation systems used for applying fresh water and those applying animal, industrial or municipal wastewater. Turf, landscape, surface drip, and subsurface drip irrigation systems are not covered.

The original operation and maintenance manual for a piece of irrigation equipment is your primary source of information regarding its required maintenance procedures. If the manual can not be located, ask your local dealer or equipment manufacturer for a replacement.

Solid Set Irrigation Systems

Stationary irrigation systems are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). The stationary sprinkler systems is often used in irregularly shaped fields, making it difficult to give a standard layout, but there are some common features between systems. To provide proper overlap, sprinkler spacings are normally 50 to 65 percent of the sprinkler's wetted diameter. Sprinkler spacing is based on nozzle flow rate and desired application rate. Impact sprinkler spacings are typically in the range of 80 feet by 80 feet using single-nozzle sprinklers. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals, and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed. In many wastewater application systems, ball valves are installed on sprinkler risers along buffers, hillsides, or other areas where runoff or ponding is a concern.

Table 1. Annual Maintenance Procedures for Sprinklers.

Type of Sprinkler	Procedures
Pressure Gauges	Check pressure gauge, pressure transducer, or flow meter for proper operation. Follow manufacturer's guidelines for calibrating transducers or flowmeters.
Big Guns	1) Check nozzle for wear. You may need to use machinist's calipers to check ring nozzles for appropriate diameter. Replace ring if worn. 2) Check reverse rotation of gun. The gun should travel in both directions (left to right, and right to left) at the same speed. Big guns operating in partial circles (less than 360°) tend to unevenly wear bearings, adversely affecting the speed of gun rotation. If bearings are worn, it may be necessary to replace the entire gun. 3) Cover the inlet of the gun to keep out of dirt or small animals.
Impact Sprinklers	1) Check nozzles for wear. Replace dented or worn brass nozzles. Check plastic nozzles for cracks, chips, or wear patterns. Replace if necessary. 2) Check rotation of each sprinkler. Swing the impact arm 4 inches to the right and release. The sprinkler head should freely and fluidly move several inches. Repeat. Ensure that the amount of rotation is consistent each time the impact arm is released. If the amount of rotation is not consistent or not fluid, replace the sprinkler head. 3) Tape over the sprinkler nozzle and pipe base to keep out foreign objects, such as insects, rodents, dust and dirt. Remove tape before operating.

Hard-Hose Travelers

Hard-hose travelers are the most popular pieces of irrigation equipment for applying animal wastes and lagoon effluent. Properly designed and installed hard-hose travelers are one of the most efficient and reliable methods of irrigating large areas. Hard-hose travelers are expensive and highly specialized pieces of equipment that cost $12,000 to $26,000. Maintenance will ensure that your equipment lasts for many years and operates properly. Proper maintenance of irrigators will also insure that waste can safely be applied, minimizing discharges or runoff events caused by malfunctioning equipment. Table 2 provides a schedule for lubricating and checking various necessary fluids on turbine-drive and engine-drive hard-hose travelers. Consult your equipment's operation and maintenance manual and follow the specific lubrication schedule that should be followed for your irrigator.

Table 2. Lubrication and Fluids Schedule for Hard-Hose Travelers.

LOCATION	TYPE OF LUBRICANT	DAILY	EVERY TWO WEEKS	MONTHLY	YEARLY
Inlet Spindle Thrust Washer	Multipurpose Grease			X	
Inlet Swivel	Multipurpose Grease		X		
PTO Shaft (if present)	Multipurpose Grease	X			
Traverse Assembly	Multipurpose Grease		X		
Drum Bearings	Multipurpose Grease			X	
Chains (except drum)	30 wt. Oil			X	
Wheel Bearings	Multipurpose Grease				X
Turntable Bearing Ring	Multipurpose Grease			X	
Gearbox (2)	90 wt. Oil				X
Gun Cart Wheel Bearings	Multipurpose Grease			X	
Drive Engine Oil	Follow Manufacturer's Specification	X			

Center-Pivot and Linear-Move Systems

Center-pivot and linear move systems are becoming more common in North Carolina. Center-pivots are available in both fixed-pivot point and towable machines. Linear-move systems are similar to pivots but instead of moving in a circular pattern they move only forward and reverse. Pivots and linears area powered electrically (480 V-AC or diesel generator) or by a diesel-powered hydraulic drives. They range from single tower machines that cover around 10 acres to multitower machines that can cover several hundred acres. Pivots and linears use either rotary sprinklers, small guns, or spray nozzles. Drop-type spray or rotary nozzles offer the advantage of applying water close to the ground at low pressure, which results in less evaporative losses and little drift due to wind. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 pound per square inch (psi). Low pressure systems (10 – 30 psi) reduce drift at the expense of higher application rates and greater potential for runoff.

DISCONNECT POWER WHEN PERFORMING MAINTENANCE. ALWAYS disconnect electrical power before servicing or performing maintenance to the machine. If you are going to perform maintenance to the machine, YOU shut off and lock the main power disconnect. Don't trust someone else to turn the power off for you. DO IT YOURSELF and take the key with you!

Table 3. Seasonal Maintenance Checklist for Center-Pivots and Linear-Move Systems.

LOCATION	ACTION
Tower	
Ground Cable	Ensure #6 bare copper wire is connected to main panel and ground rod.
Tie-downs & Turnbuckles	All tie-down bolts (turnbuckles on towable units) are drawn up tight.
Pivot Head/swivel	Grease pivot head and ensure that collector ring is in place.
Span	1. Check flanges for leaks and tighten as necessary. 2. Check pipe drains for proper drainage and rotate the seal each season. 3. Tighten all tower and span bolts and cables. 4. Check power cable for damage and proper banding to ensure proper attachment to span.
Wheels	1. Check tire pressure. Check maintenance manual for proper pressure. 2. Tighten wheel lug bolts. All wheel lugs should be torqued to 125 foot-pounds annually. 3. Check wheel gearbox oil level. Drain annually or every 1,000 hours, whichever occurs first.
Drive Motors	1. Check flex boots for leaks and tighten bands as necessary. 2. Check motor power and ground cables for damage and good connection. 3. Check gear motor lubricant. Replace lubricant after the first year of operation and then every 3 years or 3,000 hours, which ever occurs first. Consult manufacturer for appropriate gear lubricants.
Sprinklers	1. Check sprinklers, nozzles, pressure regulators for tightness. 2. Check sprinklers for free movement. 3. Check sprinkler nozzles for damage or wear. 4. Check pressure gauge or pressure transducer for proper operation.
End Gun & Booster Pump	1. Check overhang cables for damage and proper banding. 2. Clean and ensure proper operation of end gun drain. Flip drain annually. 3. Check end gun nozzle for wear. 4. Check end gun arc setting, bearings, and brake.

Pumps

A well maintained pumping system lasts longer and needs fewer repairs. This means less downtime that may limit your ability to apply animal wastes when environmental conditions are optimal.

Set up weekly, quarterly, and annual routine maintenance and inspection schedules for systems that are run more than twice a week (Table 4). If your pump is operated less often, inspect those items listed as weekly and quarterly every 2 months. Regardless of the amount of time a pump is used, a certified operator should conduct an annual inspection of the pumping and siphon system. As stated earlier, refer to the operation and maintenance manual provided with your pump for the lubrication and maintenance required for your pump.

Table 4. Weekly, Quarterly, and Annual Maintenance for Agricultural Pumps.

Weekly	
Stuffing Box	Pumps with packing rings should leak a small amount of water while the pump is in operation. If water is not dripping from the seal, loosen the gland nuts evenly until water is just running out of the snuff box in a DROPLET form. Water should not be streaming or spraying out. Approximately 20 drops per minute is recommended for most pumps. Adjust the gland nuts EVENLY as necessary to maintain this drop rate and provide necessary lubrication and cooling of the packing. If packing is tightened to the limit of the packing gland travel, additional packing is necessary.
Mechanical Seals	Pumps with mechanical seals, instead of packing rings and snuff boxes, should not leak. If leaks are detected, ensure that the pump housing bolts are tightened thoroughly. If leaks still continue, contact your pump provider or distributor.
Vibration	All rotating machines produce some amount of vibration. Excessive vibration, however, can reduce the life of your pumping and power unit. If a vibration seems excessive, stop operation, determine the cause, and correct.
Noise	When the unit is in operation, listen closely for unusual sounds that might indicate the unit is operating improperly. Determine the cause and correct.
Suction Line	Inspect line and screen for flow obstruction.
Quarterly	
Piping Connections	Inspect all system piping connections for leaks and misalignment. Misalignment of pipe connections will put excessive strain on the pump case and may cause damage to internal components of both the pump and motor. If stress on the pump case is suspected, adjust pipe supports to correct. For flange connections, shut down the pump, and remove the pipe flange bolts on the pump connections to check for misalignment. If the mating flanges come apart or shift, there is pressure at the connection(s) and adjustments should be made to the pipe supports until flanges mate without force.
Pump Foundation	Check foundation and for soundness and see that all securing bolts or lags are secure.
Lubrication	Complete all quarterly lubrications recommended in your operation and maintenance manual for you pump.
Snuff Box and Mechanical Seals	Inspect pump packing gland or mechanical seal for possible replacement. Examine shaft sleeve, if present, for wear and replace if necessary.
Pump and/or Motor Bearing	Inspect bearings for signs of wear. Repack or replace as required.
Annually	
Pumping System	Inspect the entire pump and pumping system for signs of wear.
Valves	Inspect system valves, screens, etc. Ensure that all valves are fully operational and not frozen. Lubricate or replace if necessary.
Impeller	Check pump impeller eye or proper clearance. Specific clearance specifications can be found in the pump's operation and maintenance manual or from the pump manufacturer or local distributor.
Pump Housing	Inspect pump impeller, volute case (housing), and seal chamber for signs of excessive wear or corrosion.
Hand Primer	Ensure the hand primer is operating properly. Disassemble and inspect the diaphragm for excessive wear or cracks. Replace if necessary.

Power Units

Both diesel engines and electric motors are used to power irrigation pumps. A well maintained engine system lasts longer and needs fewer repairs. The following tables provide a routine and annual maintenance and inspection schedule for pumps with electric motors (Table 5) or diesel engines (Table 6). The required maintenance and lubrication procedures should be followed daily, yearly, and for various intervals of engine operating time.

Table 5. Inspection and Maintenance Schedule for Electric Motors that Power Irrigation Pumps.

REQUIRED ACTION	SCHEDULE	PROCEDURE
Motor Bearings	Quarterly	Inspect motor bearings for signs of wear. Repack or replace as required.
Pump Foundation	Quarterly	Check the electric motor's foundation and for soundness. See that all securing bolts or lags are secure.
Lubrication	Quarterly	Complete all quarterly lubrications recommended in your operation and maintenance manual for your motor/pump.
Vibration	Quarterly	All rotating machines produce some amount of vibration. Excessive vibration, however, can reduce the life of your pumping and power unit. If a vibration seems excessive, stop operation, determine the cause, and correct.
Noise	Quarterly	When the unit is in operation, listen closely for unusual sounds that might indicate the unit is operating improperly. Determine the cause and correct.
Motor Windings	Annually	Check motor windings for degradation, rewind if necessary.
Terminal Connections	Annually	Check to ensure that terminal screws and wire connections are tight. After several years, normal heat and temperature fluctuations tend to loosen terminal screws and wire connections.

Winterization and Storage Procedures

To prevent damage, properly store your irrigator, engine, and pump anytime it will not be operating for several months. Preparing equipment for winter storage also allows you to conduct annual inspections and make necessary repairs. If possible, remove equipment from the field and store it in a clean, dry, covered storage area. The following tables (Tables 7 – 10) will help you minimize corrosion and deterioration of hard-hose travelers, irrigation pumps and diesel-powered pumping units.

Table 6. Inspection and Maintenance Schedule for Diesel Motors that Power Irrigation Pumps.

REQUIRED ACTION	SCHEDULE	NOTES
Check Engine Oil and Coolant Level	Daily	
Check Fuel Filter	Daily	
Lubricate PTO Release Bearing	Daily	DO NOT over-lubricate and avoid getting oil on clutch facings.
Check Dust Unloader Valve on Air Cleaner (if installed)	Daily	Check for air leaks and degraded rubber.
Lubricate PTO Clutch Shaft Bearings	Every 100 Hours	
Change Initial Engine Oil and Filter	Every 100 Hours	Initially change engine oil after 100 hours and then every 250 hours thereafter. Ensure that oil filter meets engine performance standards; refer to operation and maintenance manual.
Service Fire Extinguisher	Every 100 Hours	
Service Battery	Every 250 Hours	
Change Engine Oil and Filter	Every 250 Hours	Check operation and maintenance manual for recommended weight oil and approved filters.
Check Fan and Alternator Belt Tension.	Every 250 Hours	Do not pry against alternator rear frame. Once adjusted, recheck tightness of belts after operating 10 minutes.
Check PTO Clutch Adjustment	Every 250 Hours	Measure clutch engagement force at the handle grip using a spring scale. Force should be between 60 – 70 lbs.
Initial Engine Valve Clearance	400 Hours	Initially check valve clearance after 400 hours and then every 1,200 hours thereafter. Consult engine operation and maintenance manual or dealer.
Lubricate PTO Clutch Internal Levers and Linkage	Every 600 Hours or Annually	
Clean Crankcase Vent Tube	Every 600 Hours or Annually	
Check Air Intake Hoses and Connections	Every 600 Hours or Annually	The air intake system must not leak. Even the smallest leak may cause dame to the engine.
Replace Fuel Filter Element	Every 600 Hours or Annually	
Check Cooling System	Every 600 Hours or Annually	
Check Coolant Solution	Every 600 Hours or Annually	Add inhibitor as needed
Replace Air Cleaner Elements and Check Air Intake System	Every 600 Hours or Annually	
Perform Engine Tune-Up	Every 1,200 Hours or Every Other Year	
Check and Adjust Engine Speeds	Every 1,200 Hours or Every Other Year	Consult engine operation and maintenance manual or dealer.
Adjust Engine Valve Clearance	Every 1,200 Hours or Every Other Year	
Check Fuel Injection System	Every 1,200 Hours or Every Other Year	Consult your authorized engine repair station, servicing dealer, or distributor.
Inspect Turbocharger (if installed)	Every 1,200 Hours or Every Other Year	Check for excessive radial or axial play of compressor wheel and turbocharger boost pressure. Consult your servicing dealer or distributor.
Check Crankshaft Vibration Damper	Every 1,200 Hours or Every Other Year	Grasp vibration damper with both hands and attempt to turn in both directions. If rotation is felt, replace damper. Replace damper every 4,500 hours or every 5 years.
Flush Cooling System and Replace Thermostats	Every 1,200 Hours or Every Other Year	Flush with water before using a heavy duty cooling system cleaner. Fill system with only approved coolants.
Check Pressure Test Cooling System	Every 1,200 Hours or Every Other Year	Consult your authorized engine repair station, servicing dealer, or distributor.
Inspect and Service Air Cleaner Elements	As Required	When cleaning and washing primary element, remember to wash is a solution of warm water and filter element cleaner. NEVER use compressed air, gasoline, or other solvents. DO NOT oil element.

Table 7. Winterization and Storage Procedures for Hard-Hose Travelers.

REQUIRED ACTION	PROCEDURE
Purging Hose	The best method of removing water from a hard hose traveler is purging the hose with compressed air. If your irrigator is not equipped with an air-purging cap, ask your equipment distributor if one is available. Air purging will allow you to remove 85% of all of the water from your reel without risking damaging the hose when rolling up dry or from miswraping. 1. Retract hose from field and lower cart to the ground. Ensure that the cart/hose is pointed away from farm workers, vehicles, equipment, and structures. 2. Remove drain cap on cart or open drain valve. 3. Attach air-purging cap to the inlet of the irrigator. Attach hose from compressor to air-purging cap. 4. Start air compressor and build up at least 100 psi of pressure. When achieved, open valve and begin to purge the water from the irrigator. 5. DO NOT STAND near or in front of the cart during purging. Once pressure is built up in the hose, water will be blown from the irrigator at a great force. 6. Once water is blown from the reel, finish retracting the hose and cradle gun cart. Continue with off-season storage procedures.
Draining Hose	Follow this procedure only if your equipment cannot be purged with compressed air. 1. Tow the hose out to the full length and open plug or drain valve on cart. **NOTE: Leave at least ½ coil of hose on the drum to prevent pulling the hose off of the reel. 2. Rewind hose slowly with PTO or engine drive. This will allow water to drain from the reel and prevent damage from freezing. 3. DO NOT leave the reel unattended during the draining process. The hose will have a tendency to flatten slightly and miswrap. You may need to manually adjust the hose position on the drum using a wooden pole to pry the hose in place. 4. Check hose for any cracks, damage ,or loose connections. Replace or repair as necessary. 5. Replace/close drain plug or drain valve. 6. After removing the irrigator from storage, a full pull of the traveler should be made. This will ensure that no changes occur to the mechanical speed compensation devices on the equipment.
Drive Turbine	Open gate valve and drain plug or petcock on turbine assembly.
Fittings	Lubricate all fittings with multipurpose grease or appropriate weight oil.
Chassis	Touch up any scratched or chipped paint and repaint any rusted areas.
Big Gun	1) Check nozzle for wear. You may need to use machinist's calipers to check ring nozzles for appropriate diameter. Replace any worn rings. 2) Check reverse rotation of gun. The gun should travel left to right and right to left at the same speed. Big guns operating in partial circles tend to unevenly wear bearings, adversely affecting the speed of gun rotation. If bearings are worn, it may be necessary to replace the entire gun. 3) Cover the inlet of the gun to prevent the entrance of dirt or small animals.
Tires	1. Check tires for wear and cracks. 2. Reduce tire pressure to 15 psi for off-season storage. Inflate tires to 40 – 45 psi before operating.
Drive Engine	1. Change engine oil. 2. Clean/replace air filter as necessary.
Safety Shields	Check for the presence of all manufacturer's safety shields. Tighten and replace safety shields as necessary.
Chains	(Optional) Remove and store all chains in a lubricant, such as diesel fuel.
Storage	1. Store reel in a clean, dry place. 2. Block irrigator to remove the weight of the machine from the wheels. 3. If the reel is left outside, cover the entire machine with a waterproof canvas.

Table 8. Winterization and Storage Procedures for Center Pivot and Linear Move Systems.

REQUIRED ACTION	PROCEDURE
Flushing	Flush after pump repair, structural repair, winterization, season start-up, and as often as necessary to remove accumulated sand and debris. Excessive sprinkler clogging or wear can indicate high debris or sand content. 1. Turn main power off! Only water is required to flush the unit – the pivot/linear does not need to run. Ensure that the machine is not under water pressure. **REMOVING SAND TRAP PLUGS WHILE UNDER PRESSURE MAY CAUSE INJURY OR DEATH!** 2. Remove pipe drains at each tower. Clean sand and foreign particles from these drains. Flip rubber seals when reinstalling (step 6). 3. Remove the sand trap from the last regular drive tower. Clean sand and foreign particles from these drains and spray nozzles (if installed). 4. Remove the plugs in the overhang. 5. Start the engine/pump and allow the machine the flush thoroughly. 6. Turn off water supply. Reinstall all pipe drains, sand traps, and plugs. After flushing for winterization, be sure the water has drained completely from all drains before replacing drains and plugs to prevent freezing and splitting of the pipeline.
Booster Pump	Drain the booster pump. Ensure supply line is not plugged with sand or debris. Remove drain plug.
Valve or Sensor Strainers	Selenoid valve or sensor strainers should be cleaned at least once a year. Remove the strainer housing and wash strainer by running fresh water through the strainer. Avoid scrubbing the strainer to remove collected particles for this may damage the mesh.
Towable Hubs	Towable hubs should be greased thoroughly.
Parking the Machine	Steel will expand and contract with variation in temperature. When in operation this process posses no threat, but when equipment is parked, shrinkage could cause severe structural damage. The stress to contraction of the steel is more severe in longer machines. Irrigators 1,500 feet or longer are susceptible to these stresses and may exhibit shrinkage of 8-12 inches when wheel tracks are a problem. Refer to your manufacturer's or operator's manual or follow one of the following methods when parking the machine in the off-season: 1. Park the machine in an area where wheel tracks have been eliminated. 2. Place wooded planks, (2 x 12 inch), over the wheel tracks. Park the machine with the ties centered on the planks. 3. Remove all wheel tracks and run machine 100 - 200 yards. Only operate units (dry) if the temperature is above 40° F. 4. Disconnect machines with spans taller than 8 – 10 feet. Secure spans with chains to allow for contraction during cold weather.

See Table 6 for additional seasonal maintenance procedures.

Table 9. Winterization and Storage Procedures for Agricultural Pumps.

REQUIRED ACTION	PROCEDURE
Paint Pump Housing	Remove all exterior dirt and grime that may trap moisture. Prime and repaint any exposed metal to prevent corrosion.
Flush Suction and Discharge Lines	Flush suction and discharge lines. Check for leaks and replace worn gaskets.
Drain Pump Casing	Remove the lowest plug on pump and drain casing.
Lubricate Bearings	Lubricate bearings according to operation and maintenance manual.
Provide Storage	If possible, keep unit in clean, dry storage area to prevent corrosion.
Seal Open Ports	Seal all open ports to keep out foreign objects, such as insects, rodents, dust, and dirt.
Rotate Drive Shaft	Rotate dive shaft periodically to prevent freeze-up of internal components.

Table 10. Winterization and Storage Producers for Diesel Engines that Power Agricultural Pumps.

STEP	ACTION ITEM	PROCEDURE
1	**Engine Oil and Filter**	Change engine oil and oil filter.
2	**Air Filter**	Service air filter according to operation and maintenance manual.
3	**Cooling System**	Draining and flushing of cooling system is not required if engine will be store for several months. However, for longer than a year, drain the cooling system and refill according to operation and maintenance manual.
4	**Fuel Tank**	Drain the fuel tank and add 1 oz. Of inhibitor to the fuel tank for each 4 gallons of tank capacity.
5	**Crankcase Oil**	Add 1 oz. of inhibitor to the engine crankcase for each quart of crankcase oil.
6	**Air Intake**	Disconnect all air intake piping from the manifold. Pour 3 oz. of inhibitor into the intake system and replace piping.
7	**Start Engine**	Crank engine several revolutions with starter, while NOT allowing the engine to start.
8	**Belts**	Loosen fan and alternator belts to relieve tension. Remove belts if desired.
9	**Batteries**	Remove and clean batteries. Store in cool, dry placed and keep fully charged.
10	**PTO Clutch**	Disengage PTO clutch.
11	**Engine Openings**	Seal all openings on engine with plastic bags and tape. Contact engine dealer for specialized storage kits.
12	**Exposed Metal**	Coat all exposed metal surfaces with grease or corrosion inhibitor.
13	**Engine Exterior**	Clean the exterior of engine and touch-up any scratched or chipped painted surfaces.
14	**Engine Storage**	Store engine in a dry, protected area to prevent additional corrosion. If stored outside, cover with waterproof canvas or other suitable material, and seal ends with a strong waterproof tape.
	Removing Engine From Storage	
1	**Protective Coverings**	Remove all protective coverings from engine. Unseal all openings and remove covering from electrical system.
2	**Batteries**	Remove batteries from storage. Install batteries, and connect the cables.
3	**Belts**	Install new fan and alternator belts (if needed). Adjust belt tensions to appropriate specifications (refer to operation and maintenance manual).
4	**Fuel Tank**	Fill fuel tank.
5	**Start-up Checks**	Perform all start-up checks specified in operation and maintenance manual.
6	**Starting Engine**	1. Crank engine for 20 seconds, while not allowing the engine to start. Then start engine. DO NOT operate the starter more than 30 seconds at a time. Wait at least 2 minutes for starter to cool before trying again. 2. Operate engine at slow idle for several minutes. Warm up engine and check all gauges before initiating pump and placing the engine under load.