GEORGIA
DEPARTMENT OF NATURAL RESOURCES

ENVIRONMENTAL PROTECTION DIVISION

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GUIDELINES FOR SLOW-RATE LAND TREATMENT OF WASTEWATER

Revised June 2018

State of Georgia
Department of Natural Resources
Environmental Protection Division
Watershed Protection Branch

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DEFINITIONS

a. **"Composite Sample"** means a combination of at least 8 discrete sample aliquots of at least 100 milliliters, collected over periodic intervals from the same location, during the operating hours of a facility over a 24 hour period. The composite must be flow proportional.

b. **"Daily Discharge"** means the discharge of a pollutant measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the daily discharge is calculated as the total mass of the pollutant discharged over the day.

c. **"Drip Irrigation Field"** means the wetted application area or irrigation of the land treatment system or land disposal system where treated wastes, treated effluent from industrial processes, agricultural or domestic wastewater, domestic sewage sludge, industrial sludge or other sources is applied to the land using drip emitters, excluding the buffer zone.

d. For the purposes of these guidelines **"Discharge of a Pollutant"** means any addition of any "pollutant" or combination of pollutants to "waters of the State" from any "point source." This definition includes additions of pollutants into waters of the State from: surface runoff which is collected or channeled by man; discharges through pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works. This term does not include an addition of pollutants by any "indirect discharger."

e. **"DMR"** means Discharge Monitoring Report.

f. **"EPD"** means the Environmental Protection Division of the Department of Natural Resources.

g. **"Effluent"** means wastewater that is discharged (treated or partially treated).

h. **"Geometric Mean"** means the *n*-th root of the product of *n* numbers.

i. **"Groundwater"** means the part of the subsurface water in the saturated zone

j. **"Hydraulic Loading Rate"** means the rate at which wastes or wastewaters are discharged to a land disposal or land treatment system, expressed in volume per unit area per unit time or depth of water per unit area per unit.

k. **"Indirect Discharger"** means a nondomestic discharger introducing "pollutants" to a "publicly owned treatment works."

l. "**Industrial Wastes**" means any liquid, solid, or gaseous substance, or combination thereof, resulting from a process of industry, manufacture, or business or from the development of any natural resources.

m. **"Influent"** means wastewater, treated or untreated, that flows into a treatment plant.

n. **"Instantaneous**" means a single reading, observation, or measurement.

o. **"Land Disposal System"** means any method of disposing of pollutants in which the pollutants are applied to the surface or beneath the surface of a parcel of land and which results in the pollutants percolating, infiltrating, or being absorbed into the soil and then into the waters of the State. Land disposal systems exclude landfills and sanitary landfills but include ponds, basins, or lagoons used for disposal of wastes or wastewaters, where evaporation and/or percolation of the wastes or wastewaters are used or intended to be used to prevent point discharge of pollutants into waters of the State. Septic tanks or sewage treatment systems, as defined in Chapter 511-3-1-.02 (formally in Chapter 270-5-25-.01) and as approved by appropriate County Boards of Public Health, are not considered land disposal systems for purposes of Chapter 391-3-6-.11.

p. **"Land Treatment System"** means any land disposal system in which vegetation on the site is used for additional treatment of wastewater to remove some of the pollutants applied.

q. **"Limiting Design Parameter"** means the factor by which design of a system (ie permitted loading) is governed, such as groundwater mounding or nitrogen balance.

r. **"MGD"** means **million gallons per day.**

s. **"Monthly Average Limit"** means the highest allowable average of daily discharges over a calendar month, unless otherwise stated, calculated as an arithmetic mean of the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during the same calendar month.

t. **"OMR"** means Operating Monitoring Report.

u. **"Point Source"** means any discernible, confined, or discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water runoff.

v. **"Pollutant"** means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, industrial wastes, municipal waste, and agricultural waste discharged into the waters of the state.

w. **“Quarter”** means the first three calendar months beginning with January and each group of three calendar months thereafter (also known as calendar quarters).

x. **“Quarterly Average”** means the arithmetic mean of values obtained for samples collected during a calendar quarter.

y. **“Rule(s)”** means the Georgia Rules and Regulations for Water Quality Control.

z. **“Spray Field”** means the wetted area of the land treatment system or land disposal system where treated wastes, treated effluent from industrial processes, agricultural or domestic wastewater, domestic sewage sludge, industrial sludge or other sources is applied to the land via spray, excluding the buffer zone.

aa. **"Sewage"** means the water carried waste products or discharges from human beings or from the rendering of animal products, or chemicals or other wastes from residences, public or private buildings, or industrial establishments, together with such ground, surface, or storm water as may be present.

bb. **“Sewage Sludge”** means solid, semi-solid, or liquid residue generated during the treatment of domestic sewage or a combination of domestic sewage and industrial wastewater in a treatment works. Sewage sludge includes, but is not limited to scum or solids removed in primary, secondary, or advanced wastewater treatment processes. Sewage sludge does not include ash generated during the firing of sewage sludge incinerator, grit and screenings generated during preliminary treatment of domestic sewage in a treatment works, treated effluent, or materials excluded from definition of "sewage sludge" by O.C.G.A. § 12-5-30-.3(a)(1).

cc. **"Sewage system"** means sewage treatment works, pipelines or conduits, pumping stations, and force mains, and all other constructions, devices, and appliances appurtenant thereto, used for conducting sewage or industrial wastes or other wastes to the point of ultimate disposal.

dd. **“Sludge”** means any solid, semi-solid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility exclusive of the effluent from a wastewater treatment plant.

ee. **“State Act”** means the Georgia Water Quality Control Act, as amended (Official Code of Georgia Annotated; Title 12, Chapter 5, Article 2).

ff. **“Treatment System”** means the wastewater treatment facility that reduces high strength organic waste to low levels prior to the application to the irrigation field.

gg. **“Treatment Requirement”** means any restriction or prohibition established under the (State) Act on quantities, rates, or concentrations, or a combination thereof, of chemical, physical, biological, or other constituents which are discharged into a land disposal or

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land treatment system and then into the waters of the State, including but not limited to schedules of compliance.

hh. **"Water**" or **"Waters of the State"** means any and all rivers, streams, creeks, branches, lakes, reservoirs, ponds, drainage systems, springs, wells, and all other bodies of surface or subsurface water, natural or artificial, lying within or forming a part of the boundaries of the State which are not entirely confined and retained completely upon the property of a single individual, partnership, or corporation.

ii. **"Water Table"** means the top water surface of an unconfined aquifer at atmospheric pressure.

jj. **"Weekly Average Limit"** means the highest allowable average of daily discharges over a consecutive calendar week, calculated as the sum of all daily discharges measured during a calendar week divided by the number of daily discharges measured during that week. The calendar week begins on Sunday at 12:00 a.m. and ends on Saturday at 11:59 p.m. A week that starts in a month and ends in another month shall be considered part of the second month.

1.0 INTRODUCTION

1.1 Purpose

This document provides guidelines and criteria for the planning, design, and operation of slow-rate land treatment systems in Georgia that utilize spray or drip irrigation. This document consolidates and revises the following two previous documents: Guidelines for Slow-Rate Land Treatment of Wastewater Via Spray Irrigation (Georgia DNR, 2010), and Guidelines for Land Treatment of Municipal Wastewater by Drip Irrigation (Georgia DNR, 1996). These guidelines and criteria do not apply to systems utilizing overland flow, constructed wetlands, or rapid infiltration. The terms "Land Treatment System" and "Land Application System" are used interchangeably throughout this document.

The term slow-rate land treatment as used in this document refers to the treatment of domestic and industrial wastewater by irrigation onto land to support vegetative growth. These systems are to be designed and operated so that there is no point source discharge to surface waters. The irrigated wastewater evaporates and/or transpires to the atmosphere or enters the groundwater through percolation. Organic constituents in the wastewater are stabilized by soil bacteria. Organic and ammonia nitrogen are taken up by plants, nitrified by soil bacteria, lost to the atmosphere through denitrification, and minimally leached into the groundwater. Phosphorus and other constituents are adsorbed in the soil profile and taken up by plants. Properly designed and operated land treatment systems produce a percolate water of high quality and thus protect ground and surface water resources.

The criteria in this document apply to domestic and industrial wastewater systems, including systems permitted to municipal governments, authorities as well as private individually-permitted systems (such as for subdivisions), and industrial non-animal wastes. Animal wastes are regulated as Concentrated Animal Feed Operations (CAFOs) under a separate process.

The design and operation of land treatment systems are very site-specific. Hydrogeological conditions vary widely throughout the State and site assessment and monitoring requirements may vary not only from region to region, but even from site to site within the same region.

1.2 Sources of Information

The Environmental Protection Division (EPD) recommends the following additional sources of information for the planning, design and operation of slow-rate land treatment systems.

1.2.1 Organizations

a. Georgia Automated Environmental Monitoring Network
b. The Irrigation Association
c. Natural Resources Conservation Service
d. National Oceanic and Atmospheric Administration
e. U.S. Environmental Protection Agency
f. University of Georgia College of Agricultural & Environmental Sciences
g. University of Georgia Warnell School of Forestry and Natural Resources

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2.0 PROCEDURES FOR STATE REVIEW AND APPROVAL

2.1 Proposal for Land Treatment and Site Inspection and Concurrence

The *Georgia Water Quality Act* (O.C.G.A. 12-5-20 et. seq) and the *Georgia Rules and Regulations for Water Quality Control* (391-3-6 et. seq.) govern procedures necessary to gain State of Georgia approval for slow-rate land treatment systems. The steps outlined in Table 2.1-1 are in accordance with the Act and Rules. These steps are explained in the following sections. Projects funded under the State Revolving Loan Fund Program (SRF) (Title VI of the *Federal Clean Water Act*) must meet certain federal requirements in addition to the steps listed in Table 2.1-1.

The owner, the owner's engineer or agent must submit to EPD a letter of intent and Site Selection and Evaluation Report to develop a slow-rate land treatment system. The letter should indicate the projected design flow for this system and proposed source(s) of project funding. The letter should also request a site inspection. The report must identify potential land treatment sites and provide a preliminary environmental and soil evaluation of selected sites. Table 2.1-2 outlines information generally needed in the Site Selection and Evaluation Report. Additional information may be required as needed.

Upon receipt of the report, an EPD representative will inspect the selected site(s). A preliminary site concurrence or denial letter will be written based on an engineering and geologic evaluation of site conditions. It should be noted that site concurrence is preliminary and pertains only to general wastewater treatment and application to the land. The letter will indicate what requirements are necessary to proceed with the project. Site concurrences for slow-rate land treatment are valid for one year. If detailed design has not begun within this period, EPD may choose to reevaluate the project.

2.2 Environmental Information Document (municipal systems only)

After a site has been selected and accepted by EPD as suitable for slow-rate land treatment for municipalities, an Environmental Information Document (EID) must be completed, prior to the DDR. The EID shall be a short and concise document that adequately discusses the environmental impact of the proposed project and is not expected to be a complete environmental impact study. The preparer of the document should consider the environmental impacts identified in EPD's *Environmental Information Guidance Document*. All areas may not be pertinent for each project and the degree of detail will vary depending on the project size and location. The EID must bear the stamp of a Professional Engineer registered in the State of Georgia.

When the EID is completed and prior to submitting it for EPD review, the owner must conduct at least one public meeting. The purpose of the meeting is to allow public input regarding the proposed project, its purpose, its design, and its environmental impacts. The meeting date and time must be advertised at least 30 days in advance in local newspapers with circulation covering all areas impacted by the project. The owner must make provisions to receive written comments from the public. Minutes of the public meeting, proof of advertisement, and opinions derived from the meeting must be submitted to EPD with the EID.

2.3 Design Development Report

After a site has been selected by the owner and accepted by EPD as suitable for slow-rate land treatment, the owner must prepare a Design Development Report (DDR) and Soil Investigation Report. The DDR must bear the stamp of a Professional Engineer registered in the State of Georgia. The Soil Investigation Report must bear the stamp of a Professional Geologist registered in the State of Georgia. The reports should include, but are not limited to, the information outlined in Tables 2.2-1 and 2.2-2.

2.4 Permitting of Slow-Rate Land Treatment Systems

2.4.1 Trust Indenture

In order to ensure continuity of operation and maintenance, a trust indenture is required for all privately-owned domestic wastewater irrigation systems. The permittee must attempt to acquire a trust indenture with a local government. If a local government is not willing to serve as a trustee, EPD will consider allowing a non-governmental entity as trustee. In either case, we recommend that appropriate financial security be provided to allow continued operation of the system. Typically, the financial security is in the form of a bond or letter of credit with the minimum amount being equal to the cost of major component replacement, as well as projected operation and maintenance costs of the facility, for three years. EPD has developed a sample trust indenture document that is available upon request.

2.4.2 Public Notice, Draft and Final Land Application System (LAS) Permits

Upon EPD concurrence with the EID (municipal systems only) and DDR, the owner of the proposed facility must submit a written application for a Georgia Land Application System (LAS) Permit. Upon receipt of a completed application for this permit, EPD will prepare a draft LAS Permit and public notice for the project. One copy of the public notice will be transmitted to the owner for local advertisement and one copy will be published by EPD. The cost of the local advertisement is to be borne by the owner.

A 30-day comment period follows the publication date of each public notice. EPD must then respond to the comments received and will make a recommendation for issuance or denial of the permit. If no significant adverse public comments are received, a final LAS Permit may be issued for the slow-rate land treatment system.

2.4.3 Operations Manual

An outline for the scope of the Operations Manual (OM) required for the system is presented in Appendix Section 6.1. The OM is written by the owner or owner's engineer during construction of the system. The OM must be submitted to EPD prior to authorization to operate (domestic

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systems) or prior to completion of construction (industrial systems). The OM must address wastewater application rates, irrigation field cycling, monitoring requirements, harvesting schedules, maintenance schedules, and all other information necessary for successful operation of the system.

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Table 2.1-1
STEPS FOR EPD REVIEW AND APPROVAL
OF SLOW-RATE LAND TREATMENT SYSTEMS

1.0 Letter of Intent, Site Selection & Evaluation Report submitted to EPD by owner or owner's representative
  - 1.1 EPD conducts site inspection.
  - 1.2 Site concurrence, conditional concurrence [i.e. the requirement of any special design considerations, such as a groundwater mounding study to rule out or confirm mounding as a Limiting Design Parameter (LDP)] or denial issued by EPD.

2.0 Environmental Information Document – for municipal systems only
  - 2.1 Owner holds public meeting.
  - 2.2 Submitted with minutes from public meeting.

3.0 Design Development Report and Soil Investigation Report
  - 3.1 Submitted for EPD review.
  - 3.2 Accepted by EPD as the basis for facility design, effluent characteristics of wastewater, and treatment of facility.

4.0 Application for permit to apply treated wastewater to land
  - 4.1 Permit application completed and submitted to EPD.
  - 4.2 Application reviewed and checked against DDR.
  - 4.3 Trust Indenture executed for privately owned domestic facilities.

5.0 Land Application System (LAS) Permit drafted by EPD
  - 5.1 Industrial pretreatment requirements included, if necessary.
  - 5.2 Draft permit and monitoring requirements sent to owner for comment.
  - 5.3 Draft permit modified if necessary.

6.0 Public Notice
  - 6.1 Public notice drafted by EPD.
  - 6.2 One copy transmitted to owner for advertisement, one copy advertised by EPD.
  - 6.3 30 day public comment period.
  - 6.4 Public hearing, if requested.
  - 6.5 EPD prepares response to comments.
  - 6.6 If necessary, EPD modifies permit based on comments.

7.0 Final Land Application System (LAS) Permit
  - 7.1 Signed by Division Director.
  - 7.2 Sent to the facility owner.

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8.0 Plans and Specifications
- 8.1 Submitted for EPD review.
- 8.2 Checked against approved DDR.
- 8.3 Approved by EPD for construction

9.0 Operations Manual (OM)
- 9.1 Submitted by owner for EPD review.
- 9.2 EPD may review and provide comments.

10.0 Certification of Construction Completion – for domestic systems only
- 10.1 Design engineer submits *Certification of Construction Completion*
- 10.2 EPD conducts facility inspection to verify compliance with approved plans and specifications and readiness to operate. EPD may request as-built drawings following inspection if necessary.

11.0 Authorization to commence operation – for domestic systems only
- 11.1 Owner submits written request to EPD to commence operation at design flow (new systems and expansions only).
- 11.2 EPD issues written authorization.

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Table 2.1-2
SITE SELECTION AND EVALUATION REPORT
(REQUIRED INFORMATION FOR EACH SITE UNDER CONSIDERATION)

All maps must show a graphical scale, north arrow and the proposed boundaries of the wetted application area.

1.0 Site Description
- 1.1 Location map.
- 1.2 USGS 1:24,000 scale Topographic Quadrangle Map for the area within 1 mile.
- 1.3 Soil survey map (Web Soil Survey; https://websoilsurvey.nrcs.usda.gov/).
- 1.4 Known cultural or historic resources (cemeteries, archaeological sites, etc).

2.0 Site Soil Characteristics
- 2.1 U.S. Natural Resources Conservation Service soil series and descriptions (OSD Sheets)
- 2.2 Narrative description for same including:
  - 2.2.1 Texture.
  - 2.2.2 Permeability.
  - 2.2.3 Slope on and adjacent to the proposed application area.
  - 2.2.4 Drainage.
  - 2.2.5 Depth to seasonal high water table.
  - 2.2.6 Background nitrate concentrations, and any other applicable constituents subject to a drinking water standard *(strongly encouraged at this step)*
  - 2.2.7 Depth to bedrock and any limiting layers above the water table or bedrock.
  - 2.2.8 Erodibility.
  - 2.2.9 Groundwater Pollution Susceptibility (Refer to Georgia Geologic Survey Hydrologic Atlas 20.).
  - 2.2.10 A preliminary groundwater mounding evaluation based on depth to groundwater/limiting layers & soil types, whose purpose is to identify, rule out, determine the necessary level of further investigation and/or mounding analysis, or incorporate mounding as a LDP, (Discussed further in Section 3.15.). The mounding analysis should be conducted for the full duration of planned site operations.

3.0 100-year flood elevation for site (Either give the elevation or provide supporting documentation as to how it was determined that the site is not within the 100-year flood zone). Show the nearest 100-year flood boundary(ies) on a USGS 1:24,000 scale Topographic Quadrangle Map (regardless of whether any 100-year flood boundary occurs onsite).

4.0 Existing vegetative cover.

5.0 Existing and historical land use (Identify, on a 1:24,000 scale USGS Topographic Map, the site boundaries and any known locations of potential nutrient sources onsite, on adjacent properties, or upslope, e.g. cattle grazing, garbage dumps, poultry houses, biosolids sites, fertilized crops, etc.).

6.0 Present land owner.

7.0 Identify any drinking water sources within 2,500 feet of the irrigation field.

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Table 2.2-1
DESIGN DEVELOPMENT REPORT
REQUIRED INFORMATION

All maps must show a graphical scale, north arrow and the proposed boundaries of the wetted application area.

1.0 Site Description
- 1.1 Location map
- 1.2 Climate
- 1.3 Geology (including subsurface hydrology)
- 1.4 Groundwater Potentiometric Surface Map (Include the following supporting data: monitoring well/piezometer boring logs, well/piezometer construction diagrams, and a table listing the following: calculated groundwater elevations, measured groundwater depths/dates, and surveyed top-of-casing elevations.)
- 1.5 Topography
- 1.6 Site accessibility and property boundaries for the site and surrounding parcels
- 1.7 Identify water supply wells within 2500 L.F. of facility
- 1.8 Background Nitrate concentrations on each field, and any other applicable constituents subject to a drinking water standard *(if not submitted with the Site Selection)*

2.0 Scaled drawing with 2-foot elevation contours showing the preliminary site layout, including
- 2.1 Pre-application treatment facility
- 2.2 Storage pond(s), tanks, and/or structures
- 2.3 Irrigation fields (show field number/designation, usable acreage, and total acreage)
- 2.4 Buffer zones and all surrounding properties (with elevation contours included)
- 2.5 Hand auger, test pit and soil boring locations
- 2.6 Access roads and utilities
- 2.7 Watercourses (perennial or intermittent ponds, lakes, rivers, streams, ditches, wetlands, man-made drainage areas, etc., including those on the surrounding properties)
- 2.8 Drainage Structures
- 2.9 Flood Elevations
- 2.10 Residences and habitable structures within or adjacent to site

3.0 Design wastewater characteristics and constituent removal efficiencies (influent to pre-application treatment and treated effluent to irrigation fields). If the project involves an existing facility, then historical, representative data must be used, if available.
- 3.1 Average and peak daily flows
- 3.2 Industrial Flows (Include SIC code/s and pre-treatment permitting information, if applicable)
- 3.3 Biochemical Oxygen Demand[a] (Chemical Oxygen Demand, if necessary)
- 3.4 Total Suspended Solids
- 3.5 Ammonia Nitrogen, Total Kjeldahl Nitrogen, and Nitrate-Nitrite
- 3.6 Total Phosphorus
- 3.7 Chloride
- 3.8 Sodium Adsorption Ratio [b]
- 3.9 Electrical Conductivity
- 3.10 Metals, Priority Pollutants, Primary and Secondary MCLs[c]

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4.0 Water balance and determination of design wastewater loading rates for each irrigation field (if appropriate)

5.0 Nitrogen balance and selection of cover crop and management scheme

6.0 Background/baseline groundwater samples

7.0 Phosphorus and other constituent loading rates

8.0 Determination of wetted field area(s) and required storage volume

9.0 Process design for pre-application treatment facility
- 9.1 Schematic of pump stations and unit processes
- 9.2 Basin volumes, loading rates, hydraulic detention times, etc.
- 9.3 Capacity of pumps, blowers and other mechanical equipment (information for the irrigation pump station must accompany plans and specifications submittal)
- 9.4 Preliminary hydraulic profile

10.0 Detailed Soil Investigation Report (reference Table 2.2-2)

[a] Chemical Oxygen Demand or Total Organic Carbon may be substituted for industrial wastewaters where appropriate.

[b] Sodium Adsorption Ratio = $\dfrac{Na^{+1}}{\text{SQRT}\,[(Ca^{+2} + Mg^{+2})/\,2]}$

Where Na^{+1}, Ca^{+2} and Mg^{+2} in the wastewater are expressed in milli-equivalents per liter (meq/L) and SQRT represents "square root of".

[c] Metal, priority pollutant, primary and secondary MCL analysis is required for all industrial wastewaters and municipal wastewater systems that receive industrial process wastes. Analyses required depend on the particular process wastewater being discharged and will be determined on a case-by-case basis. However, <u>in all cases the presence and proportion (i.e. %) of industrial process wastewaters must be identified.</u> All analyses must be conducted by a laboratory certified to operate in the state of Georgia.

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Table 2.2-2
DETAILED SOIL INVESTIGATION REPORT
REQUIRED INFORMATION

All maps must show a graphical scale, north arrow and the proposed boundaries of the wetted application area.

1.0 Site description
- 1.1 Location map
- 1.2 Topographic map
- 1.3 Soil Survey map
- 1.4 Hand auger, test pit and soil boring locations

2.0 Soil series descriptions (each soil present and OSD sheets)
- 2.1 Texture
- 2.2 Permeability
- 2.3 Slope
- 2.4 Drainage
- 2.5 Depth to seasonal high water table
- 2.6 Depth to bedrock
- 2.7 Erodibility

3.0 Soil characteristics (each soil series present)
- 3.1 Hand auger, test pit and soil boring logs
  - 3.1.1 Soil horizons
  - 3.1.2 Depth to groundwater (including seasonal high water table)
  - 3.1.3 Depth to bedrock and any limiting layers above the water table or bedrock
- 3.2 Unified Soil Classification
- 3.3 Results from saturated hydraulic conductivity testing
- 3.4 Results from soil chemistry testing
  - 3.4.1 pH
  - 3.4.2 Cation Exchange Capacity
  - 3.4.3 Percent Base Saturation
  - 3.4.4 Phosphorus Absorption
  - 3.4.5 Nutrients (N, P, K)
  - 3.4.6 Agronomic trace elements
  - 3.4.7 Sodium Absorption Ratio
- 3.5 Engineering properties of soils proposed for pond construction
  - 3.5.1 Clay content
  - 3.5.2 Permeability
  - 3.5.3 Plasticity

4.0 Identification of subsurface conditions adversely affecting vertical or lateral site drainage (Including a groundwater mounding analysis, if warranted. See Section 3.15 for further discussion.)

5.0 Delineation of soils and areas suitable and not suitable for land treatment

6.0 Determination of design percolation for each soil type [and/or the hydrogeological regime for any areas where groundwater mounding is the Limiting Design Parameter (LDP). See Section 3.15 for further discussion.]. A separate hydro-geologic determination report may be necessary.

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2.5 Engineering Plans and Specifications

2.5.1 Review

After EPD concurrence with the Design Development Report (DDR), the owner must submit detailed construction plans and specifications that have been completed in accordance with EPD's current rules and guidelines and bear the stamp of a Professional Engineer registered in the State of Georgia. Pump curves and hydraulic calculations for the distribution system must accompany the plans and specifications, and each of these items will be reviewed for consistency with the DDR and accepted engineering standards. Upon review of the plans and specifications and issuance of the final LAS Permit, a letter approving the plans and specifications for construction can be written. This approval is valid for one year. If construction has not begun within this period, the project may require reevaluation.

IMPORTANT: Plans and specifications will not be approved for construction until a final LAS Permit for the facility has been issued. Detailed design work undertaken prior to permit issuance is at the owner's risk. Approval for construction of a privately-owned LAS is contingent upon execution of a trust indenture and issuance of the final permit (ref. Sec 2.3.1).

2.5.2 Construction

EPD may choose to make interim inspections of projects under construction to ascertain their progress and adherence to the approved plans and specifications. Upon project completion of domestic systems, the design engineer or owner must certify to EPD, in writing, that the project was constructed in accordance with the approved plans and specifications. Upon receipt of this certification, an EPD representative will inspect the completed facility. When the facility is verified as being complete and operational, the permittee must submit to EPD a written request for authorization to operate the facility at the permitted flow limits. Once all of these steps are completed, EPD will issue a letter to the permittee formally authorizing operation under the facility's LAS Permit.

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3.0 GUIDELINES AND CRITERIA FOR DESIGN

3.1 Suitability of Sites for Land Treatment

3.1.1 Location

There are two, often contradictory, requirements for slow-rate land treatment sites: proximity to the wastewater source and a large tract of suitable, undeveloped land. Additional considerations include a moderate degree of isolation, ease of access, soil suitability, availability of utilities, protection from flooding, and suitable hydrogeological conditions. Land treatment systems can be developed on agricultural land and in forests. Irrigation of public areas, such as golf courses, cemeteries, green areas, and parks, are considered urban water reuse projects and a separate set of guidelines applies to such systems.

3.1.2 Topography

Maximum grades for wastewater spray irrigation fields are generally limited to 7 percent for row crops, 15 percent for forage crops and 30 percent in forests. Maximum grades for wastewater drip irrigation fields are generally limited to between 20% and 25%, and up to 30% in forests. Drip systems on slopes which exceed this criteria may be approved by the Division on a case by case basis. Sloping sites promote lateral drainage and make ponding and extended saturation of the soil less likely than on level sites. However, side-slope groundwater breakouts may result from any excessive groundwater mounding (See Section 3.15 for further discussion of mounding).

Convex landscapes with low drainage density are the ideal landscape for land application, allowing uniform distribution of effluent across the landform and optimal land utilization. Areas with high drainage density (the number of intermittent and perennial streams per unit area) are indicative of lower landscapes that receive significant volume of storm water input. In addition, the required drainage buffers will reduce the usable area and economic feasibility. Concave landscapes tend to concentrate water and should be either avoided or considered for lower than typical applications. Karst topography occurs in some areas of Georgia's Coastal Plain and Valley and Ridge provinces (i.e. southern and northwestern Georgia, respectively) that are underlain by carbonate bedrock (i.e. limestone or dolomite). Karstic terrain typically consists of internally-drained topographic depressions, and karstic aquifers are characterized by solution cavities and conduit flow of groundwater. These characteristics render karstic areas inherently more susceptible to groundwater pollution. Therefore, LASs proposed for karstic areas/aquifers require special consideration and may warrant increased buffers or other site-specific limitations.

3.1.3 Soils

In general, soils with a USDA Natural Resources Conservation Service (NRCS) permeability classification of moderate to moderately rapid (0.6 to 6.0 inches/hour) are suitable for wastewater irrigation. However, published soil classifications do not necessarily indicate the suitability of all groundwater and drainage conditions, nor do they indicate the hydrogeological conditions below the depth of the soil profile. Soils or subsurface lithologies that are poorly drained have high groundwater tables, or restrictive subsurface soil or lithological layers may not be suitable for slow-rate land treatment without application-rate reductions, and/or operational controls. For example, in order to avoid diminished treatment capacity and/or side-slope breakouts at LASs where groundwater mounding is the LDP, it might be necessary to designate a sentinel monitoring well in which a critical groundwater maximum threshold elevation would trigger the temporary limitation or cessation of any further application until the water table drops back below the threshold.

3.2 Soil Investigations

3.2.1 General

Soil investigations for land treatment differ greatly from investigations for foundations, roads, and other civil engineering works. As a result, different investigative and testing methods are required.

The land treatment soil investigation must characterize the permeability and chemical properties of the soil profile that will act as the medium for tertiary wastewater treatment and final disposal. It must also determine the elevation of the seasonal high groundwater, establish the groundwater flow direction and gradient, and identify any subsurface / hydrogeological conditions that may limit the vertical or lateral drainage of the land treatment site. A separate hydro-geologic determination report may be necessary based on the site location. This includes conducting a groundwater mounding analysis, if necessary (See Section 3.15 for further discussion.). The number of soil samples and piezometers/monitoring wells necessary to supply all of this information will be dependent on the nature of the particular site and is a matter of professional judgment. The specific information required for design is outlined in Table 2.2-2.

3.2.3 Saturated Hydraulic Conductivity Testing

Saturated vertical hydraulic conductivity testing is required for the most limiting horizon of each soil series present. The most limiting soil horizon for each soil type should be determined from soil survey information. A minimum of five (5) tests for each soil series should be performed. **If the proposed site is to be clear-cut after the completion of the Soil Investigation, permeability tests in the upper horizon and topsoil disturbed by the clear-cutting must be done following the clear-cutting and establishment of the forage grass system.** However, clear-cutting and site disturbance should be kept to a minimum wherever possible. Testing for saturated horizontal hydraulic conductivity is additionally required for the purposes of a groundwater mounding analysis (See Section 3.15 for additional discussion of groundwater mounding.).

Acceptable methods for saturated hydraulic conductivity testing are listed in Table 5.6-4. Percolation tests as performed for septic tank drain fields are not acceptable.

The identification of the limiting layer is critical to development of feasible loading rates. Many impeding layers are obvious, such as compacted or brittle layers (Btv, Btx), rock (Cr, R) and the water table (Btg, BCg, Cg). Soil Series descriptions (OSD data) that indicate these features in the optional master horizon designations (i.e. v, x, r, g) and are a good starting point. In soils or lithologies without these features, identifying the limiting layer is more difficult. Note, however, that critical (impeding or perching) layers, or the water table itself, can occur at depths which are below the typical soil profile (e.g. below 5 or 6 feet) but which still may be at a shallow-enough depth to cause groundwater perching or mounding. Therefore, deeper lithological characterization and/or permeability testing (vertical and/or horizontal) may be necessary either to rule out or to incorporate groundwater mounding as a LDP.

3.2.4 Soil Chemical Testing

The pH, Cation Exchange Capacity, and Percent Base Saturation, of each soil series must be determined from samples taken from the A and B horizons (if present). These chemical tests determine the retention of wastewater constituents in the soil and the suitability of the soil for different cover crops. A minimum of three (3) samples for each soil series should be taken. Testing for soil nutrients (nitrogen, phosphorus, and potassium) and agronomic trace elements may be included if appropriate for the vegetative management scheme. Testing for soil nitrogen (especially) is warranted to calculate the nitrogen budget for land that was previously used to grow crops (i.e. land with a history of fertilizer application), where the irrigation and additional percolation of even very low-strength effluent could leach out residual nitrate fertilizer and cause a spike in groundwater nitrate.

Soil chemical testing should be conducted in accordance with the latest methodology published by the American Society of Agronomy, USEPA, or other recognized authority.

3.3 Pre-application Treatment Requirements

3.3.1 General

Land treatment systems have a demonstrated ability to treat high strength organic wastes to low levels. However, such systems require a high degree of management with particular attention paid to organic loading rates and re-aeration of the soil profile between wastewater applications.

EPD requires that all domestic and industrial wastewater receive biological treatment prior to irrigation. This is necessary to protect the health of persons contacting the irrigated wastewater and to reduce the potential for odors in storage and irrigation.

3.3.2 Domestic Wastewater Considerations

3.3.1.1 BOD and TSS Reduction, and Disinfection for Spray Systems

Pre-application treatment standards prior to storage and/or spray irrigation are as follows:

a. Restricted Use (No Public Access) - All domestic wastewater must be treated to a 5-day Biochemical Oxygen Demand of 50 mg/L at average design flow and 75 mg/L under peak loads. Total Suspended Solids are limited to 50 mg/L for mechanical systems and 90 mg/L for pond systems. Disinfection is generally not required for restricted access land treatment sites. EPD may, however, require disinfection when deemed necessary. If chlorine disinfection is utilized, addional sampling of the groundwater may be required to ensure maximum contaminant levels are not exceeded.

b. Limited Use (Controlled Public Access) - All wastewater must be treated to a 5-day Biochemical Oxygen Demand of 30 mg/L at average design flow and 50 mg/L under peak loads. Total Suspended Solids are limited to 30 mg/L. Disinfection is generally required, usually to achieve a fecal coliform limit of 200 MPN/100 ML.

c. Water Reuse (Unlimited Public Access) - Sites open to public access include golf courses, green areas, parks, and other public or private land not expressly closed to the public. Such projects are considered urban water reuse systems and requirements are outlined in separate EPD guidance.

3.3.2.2 BOD and TSS Reduction, and Disinfection for Drip Systems

Aerobically treated surface drip applications must be treated to a 5-day Biochemical Oxygen Demand of no more than 50 mg/L at average design flow and 75 mg/L under peak loads. The Total Suspended Solids (TSS) are limited to 50 mg/L for mechanical systems and 90 mg/L for ponds prior to passing through the drip system filters. Disinfection is generally not required. Applications utilizing surface distribution or without return piping will generally be considered for areas with Controlled Public Access. These above-surface systems will be assessed on the merits of the site selected and actual use. The requirements of water reuse systems as outlined in Section 5.0 of the EPD's *Criteria for Slow Rate Land Treatment and Urban Water Reuse* must be met for other site classifications. Subsurface systems with return piping shall be considered for use with Unlimited Public Access without having to meet the effluent requirements of water reuse systems. **Any surfacing of wastewater effluent will require the owner/operator to immediately control the access to the drip fields unless reuse requirements have been met.** The system will be reclassified for Controlled Public Access until repairs have been made which eliminate the potential for any future surfacing of wastewater effluent. Pre-application treatment requirements are the same as for other Land Application Systems (LAS). Pre-application treatment systems for subsurface drip systems should be similar to those of spray irrigation systems in that the pretreatment process should be designed and operated to minimize nitrification. The DDR should indicate the expected range of nitrogen removal in the pre-application system.

Subsurface systems utilizing emitters may be used in lieu of conventional or other alternative absorption fields in systems that follow anaerobic septic systems. Approvals for small applications ($\leq$ 10,000 GPD) may be issued by the Department of Human Resources' local health department at their discretion.

All anaerobically treated wastewater must be treated using the best practical treatment technology. Individual septic tank interceptor units with a centralized distribution system are acceptable. A minimum 1,000 gallon tank should be provided. The EPD recommends that the tanks provide at least 48 hours of detention time within the tank and suggests the use of baffling to prevent short-circuiting. For small residential districts, wastewater flows are commonly determined on the basis of population density and the average per capita contribution of wastewater. Where possible, flow rates should be based on actual flow from selected residential areas similar in social and economic makeup of the area being considered for development. When this is not possible, we recommend that a minimum of 100 gallons per capita per day be used. In sizing the tanks and distribution system, the assumption of 3.5 persons per household (3 bedroom home) should be used. Written verification of anticipated influent and effluent wastewater quality must be provided for all anaerobic treatment facilities proposed. The use of garbage disposals increases the solids (settleable and floatable) in wastewater and the rates at which they accumulate in the septic tank. This will require either more frequent pumping or a larger septic tank to keep the pumping frequency down. If garbage disposals are to be considered, the capacity of the septic tanks must be increased by 250 gallons. Notwithstanding, the Operations Manual must address the frequency and who maintains the responsibility for tank pumping and maintenance.

3.3.3 Industrial Wastewater Considerations

Domestic wastewater is usually a blend of domestic and commercial wastes with a predictable range of characteristics. Industrial wastewaters are more variable in nature with unique wastewater constituents and concentrations for each industry type (i.e. food processing, textiles, soaps and surfactant manufacturing, etc.). Some industrial wastewaters may be suitable for direct land treatment by irrigation under intensive management schemes. LAS permits receiving industrial wastewater may have a BOD, COD and/or TSS limit established after evaluating the following criteria:

a. Influent concentration and loading;
b. Suitability for biological treatment;
c. Percent reduction economically feasible to protect aerobic bacteria in the soil, human health and the control of odors;
d. Geographic location of treatment system and irrigation fields;
e. Compliance history; and
f. EPD may use additional reasonable criteria for determining BOD, COD, SAR and TSS permit limits when deemed necessary.

3.3.4 Nitrogen

Maximum nitrogen removal occurs when nitrogen is applied to the site in the ammonia or organic form. Nitrate is not retained by the soil and leaches to the groundwater, especially during periods of dormant plant growth. A description of the anticipated range of nitrogen removal should be included in the DDR, including the nitrate concentration (mg/L) in the pre-irrigated effluent. The use of septic tanks or other anaerobic treatment methods are considered acceptable for specific applications.

3.3.5 Treatment and Storage Ponds

At least two treatment cells followed by a storage pond and irrigation pump station are required for all pond pre-application treatment systems. The treatment cells may be aerated, facultative or a combined aerated/facultative system. They may be separated by earthen dikes or floating baffles. However, the storage pond and irrigation pump station must be hydraulically separate from the treatment cells (i.e., pumping must not affect hydraulic detention time in these cells). The criteria above may not be applied to existing systems currently in compliance with their permit.

IMPORTANT: If initial flows are going to be significantly below design, EPD recommends that the construction be phased. The storage pond should not be built for ultimate flow. Phasing is necessary to avoid erosion, odor, and liner failure problems that can occur in such circumstances.

Ponds used for pre-application treatment must have liners to prevent seepage from exceeding 1/8 inch/day. Either properly constructed clay or synthetic liners may be used. Facultative pond cells should have a length to width ratio of 4:1 (to minimize short circuiting) with a depth of between 3 and 5 feet. Sizing of complete and partially mixed aerated ponds should be based on first-order removal rate kinetic equations and the expected annual temperature variation. A 2-foot freeboard is recommended for all ponds less than or equal to six acres and a 3-foot freeboard is required for all ponds larger than six acres.

Ponds used for storage of treated wastewater must have liners to prevent seepage from exceeding 1/8 inch/day. Because storage ponds fluctuate greatly in water level, it is extremely difficult to maintain an effective clay liner due to drying, cracking, and erosion. EPD requires synthetic liners for storage ponds. If clay liners are used, synthetic or concrete slope protection must be used on interior slopes from six (6) inches above the maximum operational water level to one (1) foot below the lowest operational water level. An appropriate water level must be maintained at all times in clay-lined ponds. EPD recommends the use of multiple outlet points to allow for effluent draw off from different elevations within the storage pond.

Pond dikes must not exceed 3:1 for internal or external slopes. Any pond with a dike taller than 25 feet or which stores in excess of 100 acre-feet (32.6 MG) of water at maximum depth must comply with the Safe Dam Regulations of EPD.

3.4 Soil and Cover Crop Compatibility

Inorganic constituents of effluent from pre-application treatment should be compared with Table 5.6-3 to ensure compatibility with the land application site soils and cover crops.

3.5 Protection of Irrigation Equipment

Prior to pumping to the irrigation field distribution system, the wastewater must be screened to remove fibers, coarse solids, oil and grease, etc. which might clog distribution pipes, emitters, or spray nozzles. At a minimum, screens with a nominal diameter equal to the smallest flow opening in the distribution system should be provided. Some manufacturers recommend screening to remove solids greater than one third (1/3) the diameter of the smallest flow opening. The size and location of this opening must be included in the DDR. Filters should meet the sprinkler/emitter manufacturer's requirements for size, quality, and quantity (but in no case shall fewer than two filters be provided), to ensure proper continuous operation of the system. The planned method for disposal of the screenings must be provided.

Pressurized, clean water for backwashing screens should be provided. This backwash must be automated. A discussion of the controls which initiate the backwash process (i.e. differential pressure, total flow through filters, timers, etc.) must be included in the DDR. Filtered water used for backwash must be pre-filtered to at least the same degree as the filtration equipment's filtration mesh size to ensure that the filtration equipment remains clean.

Filter backwash and maintenance requirements must be addressed in the Operations Manual prepared for the system. Backwashed screenings should be captured and removed for disposal. Arrangements should be made for periodic removal of solids buildup from the system. Final disposal of filtrate debris must be done according to all state and local ordinances and should be addressed in the Operations Manual.

3.6 Determination of Design Percolation Rate(s)

3.6.1 General

One of the first steps in the design of a slow-rate land treatment system is to develop a design percolation rate. This value is used in water balance calculations to determine design wastewater loading rate(s) and thus irrigation field area requirements. The percolation rate is a function of soil/lithological permeability and drainage. Because different soil types or lithologies may have different limiting percolation rates and because the soil or lithology types may vary from field to field, it may be necessary for a system to have different design percolation rates for each field.

3.6.2 Design Percolation Rate Values

The most limiting layer, i.e. A, B, or C horizon, of each soil series must be identified. Any subsurface conditions above the water table (or above a depth of 20 feet, whichever is shallower) that limit the vertical or lateral drainage of the soil profile must also be identified. Examples of such limiting subsurface conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil (or lithological) permeability. Values of saturated vertical hydraulic conductivity from the testing of soil and lithologies above the water table (or above a depth of 20 feet) may be used to develop the design percolation rate for sites, if water-table mounding has been ruled out as a LDP, (See Section 3.15.). Note that even if water-table mounding is not a LDP, it still may be necessary to conduct saturated vertical hydraulic conductivity testing on a lithological sample that is deeper than 5 or 6 feet (i.e. deeper than the typical soil profiling depth), to identify the most limiting layer above the water table (or above a depth of 20 feet), upon which perching might occur.

Values of saturated vertical hydraulic conductivity must be modified by an appropriate safety factor to determine the design percolation rate. The safety factor reflects the influence of several elements, including: the fact that long periods of saturation are undesirable, the uncertainty of test values, the drainage characteristics of the land treatment site, the variation of permeability within the soil series, the rooting habits of the vegetation, the soil reaeration factors, and the long-term changes in soil permeability due to wastewater application. For sites where water-table mounding has been ruled out as a LDP, EPD recommends that the design percolation rate at land treatment sites be no more than 10 percent of the mean saturated vertical hydraulic conductivity of the most limiting layer above the water table.

Sites with less than five feet seasonal high groundwater, shallow bedrock, or a shallow perching unit (low permeability layer) may require reduced application rates before they can be utilized for slow-rate land treatment. The design percolation at such sites is a function of the design of the drainage system and/or application-rate reduction to prevent excessive groundwater perching or mounding, if groundwater mounding is a LDP (See Section 3.15.). A safety factor not exceeding 10 percent, should be applied to field measured values of vertical and horizontal saturated hydraulic conductivity (saturated horizontal hydraulic conductivity is one of the normal inputs into water-table mounding models).

3.7 Determination of Design Wastewater Loading Rate(s)

3.7.1 General

The design wastewater loading rate is a function of:

a. Precipitation.
b. Evapotranspiration.
c. Design percolation rate.
d. Nitrogen loading limitations.
e. Other constituent loading limitations.
f. Groundwater and drainage conditions [Including groundwater mounding if it is a Limiting Design Parameter (LDP). See Section 3.15 for further discussion.].
g. Average and peak design wastewater flows.

Therefore, developing the design wastewater loading rate is an iterative process. An initial value is selected from water balance calculations and used to determine wetted field area. This loading rate is then compared to nitrogen and other constituent loading limitations (reference Section 3.8). If the initial value exceeds these limitations, the design wastewater loading rate is reduced and the process is repeated. This iterative process is illustrated in Appendix Section 5.4.

EPD limits design wastewater loading rates (WLR_D) for non-reuse systems to a maximum of 2.5 inches/week and instantaneous wastewater application rates to 0.25 inches/hour. It is important to note that the preceding weekly and instantaneous WLR_D caps (2.5 inches/week and 0.25 inches/hour, respectively) are ***not*** default rates for the prevention of excessive groundwater mounding. The design wastewater loading may be fixed at a constant rate or may vary seasonally or monthly but it must account for site-specific climatic, drainage, and any hydrogeological limitations, such as groundwater mounding if it is a LDP. Also, because a given site may include several different soil types with significant variation in their permeabilities, or different hydrogeological conditions in different site areas (e.g. different groundwater mounding propensities), it is possible that there may be different application rates for different areas of the site. EPD recommends that when that is the case, the designer lay out fields to separate the soils/lithologies with different permeabilities and/or hydrogeological regimes. However, if the designer does not lay out separate fields and a field includes more than one soil type or hydrogeological regime, the designer should limit the application rate to the most restrictive soil permeability and/or the highest propensity for groundwater mounding, whichever is most restrictive of the allowable application rate [i.e. the LDP]. Please see Section 3.15 for further discussion of groundwater mounding.

For drip systems, considerations must be made for the depth of the dripper line and the storage capacity of the soil above the dripper. The available storage capacity should be calculated for each soil series in a drip system. Thirty five percent (35%) or less of this value should be used to determine the hourly rate of the drip emitter. This should verify that the saturated hydraulic conductivity of the soil used is adequate for the instantaneous application rate proposed for a drip system. The depth to drip emitters may be adjusted to ensure adequate storage is provided in the soil above the line. A minimum dripper burial depth of 8 inches is recommended.

3.7.2 Water Balance

Wastewater loading rates are determined from the following water balance equation:

$$WLR_D = (Evap + Perc) - Precip \qquad \textbf{eq. 3.7.2}$$

Where,	WLR_D	=	Design wastewater loading rate (in/month), may not exceed 0.36 x no. of days in the month.
	Evap	=	Potential Evapotranspiration (in/month)
	Perc	=	Design percolation rate (in/month); reference Section 3.6
	Precip	=	Design precipitation (in/month)

Example water balance calculations are presented in Appendix Section 5.4.3. From these calculations, critical water balance months (i.e., months with the smallest allowable hydraulic wastewater loading) are identified. The wastewater loading rate in the critical water balance month is WLR_C.

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3.7.3 Potential Evapotranspiration

Reliable field data for evapotranspiration are difficult to obtain. Therefore, values for average monthly potential evapotranspiration generated from vegetative, soil, and climatological data are used in water balance calculations. For row and forage cover crops, EPD suggests use of either the modified Penman or the Blaney-Criddle Method calibrated for local conditions. For forested systems or when data for other methods is not available, the Thornthwaite equation adjusted for sunlight duration and latitude can be used. The Thornthwaite equation and adjustment factors for Georgia are presented in Appendix Section 5.2. In addition to the methods listed, estimates of evapotranspiration can be obtained from published climatological resources.

The method used to estimate average monthly potential evapotranspiration for water balance calculations must be referenced in the DDR. In addition, these values should be based on a minimum record of 30 years of historical climatic data.

3.7.4 Five-Year Return Monthly Precipitation

EPD requires the use of a five-year return and monthly precipitation values in water balance calculations. Five-year return values are defined as the 80th percentile value in a 30-year ranked listing of historical monthly precipitation data. This corresponds to:

5-Year Return Precip = Precip(avg) + (0.85 x std.dev.) **eq. 3.7.4**

Where,	*Precip(avg)*	=	Average monthly precipitation from 30 or more year historic record
	std.dev.	=	Standard deviation for same

The most recent thirty-year records of both monthly precipitation and temperature are available for all of Georgia from numerous published sources. The source of precipitation data used for design must be referenced in the DDR.

3.8 Nitrogen Balance/Cover Crop Selection and Management

3.8.1 General

Land treatment systems must be designed so that nitrate concentration in the percolate does not exceed 7 mg/L. Percolate nitrate concentration is a function of nitrogen loading, cover crop, management of vegetation, and hydraulic loading. The design wastewater loading rate(s) determined from water balance calculations must be checked against nitrogen loading limitations. If for the selected cover crop and management scheme, the proposed wastewater loading rate results in estimated percolate nitrate concentrations exceeding 7 mg/L, either the loading must be reduced or a cover crop with a higher nitrogen uptake rate must be selected.

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3.8.2 Nitrogen Balance

Percolate nitrate concentrations are estimated from an annual or seasonal nitrogen balance based on the average design wastewater loading, proposed cover crop, and cover crop management scheme. An example of nitrogen balance calculations are presented in Appendix Section 5.4.4, and Tables 5.4-2 and 5.4-3.

In nitrogen balance calculations, all nitrogen not lost to denitrification, ammonia volatilization, or plant uptake is assumed to leach into the groundwater as nitrate. For row and forage crop systems, assumed losses to denitrification will not exceed 10 percent of the total nitrogen applied. In forest systems, assumed denitrification losses should not exceed 15 percent. Assumed losses to ammonia volatilization will not exceed 5 percent of the total ammonia applied. Soil storage of nitrogen should be assumed to be zero.

Table 3.8-1 below defines the recommended nitrogen uptake rates for typical cover crops utilized in the State of Georgia. If a higher nitrogen uptake rate than listed below is recommended, laboratory analysis should be provided as justification for the site specific design. Additional references are included in Section 5.6. In all cases, the source of the plant nitrogen uptake rate used for design must be referenced in the DDR.

Table 3.8-1
RECOMMENDED NITROGEN UPTAKE RATES FOR DESIGN

Cover Crop	Annual Nitrogen Uptake (lbs/acre/yr)
Coastal Bermuda Grass	350
Ryegrass	150
Tall Fescue	200
Pine with no Understory	200
Pine with Understory	250

3.8.3 Cover Crop Selection and Management

Row crops may be irrigated with wastewater only when not intended for direct human consumption. Forage crops irrigated with wastewater must be harvested and dried before feeding to livestock. Unmanaged, volunteer vegetation (i.e., weeds) is not an acceptable irrigation field cover crop and could result in a violation of the permit. Disturbed areas in forest systems must be initially grassed and replanted for succession to forest.

Cover crops require management and periodic harvesting to maintain optimum growth conditions assumed in design. Forage crops should be harvested and removed several times annually. Pine and hardwood forest systems should be harvested at intervals as recommended by the local forest service or registered forester. It is recommended that whole tree harvesting be considered to maximize nutrient removal. However, wastewater loadings following the harvesting of forest systems must be reduced until the hydraulic capacity of the site is restored.

The design may require additional irrigation field area to allow for harvesting and the regeneration cycle.

While relatively high in nitrogen and phosphorus, domestic wastewater is usually deficient in potassium, as well as trace elements needed for vigorous agronomic cover crop growth. High growth rate forage crops typically require supplemental nutrient addition to maintain nitrogen uptake rates assumed in design. Additionally, industrial wastewaters are highly variable based on the type of industry.

At least annually, the soils should be evaluated by the local extension office or other commercial laboratory to determine if soil supplements are needed. Industrial wastewaters considered for land treatment should be carefully evaluated for their plant nutrient value, as well as possible salt content, which can hamper plant growth and destroy soil structure.

Surface drip applications are presumed to pass through the root zone when percolating through the soil. When burying dripper lines it is important that the lines be placed at a depth considered within the root zone of the prospective cover crop. Contact with the local extension office should be made to ensure that the depth of the cover crop root zone is consistent with the dripper line burial depth specified in the DDR.

Forest nutrient cycling magnitudes can vary widely from site to site and over time. A justification of nutrient uptake based on the specific species and silvicultural practice proposed should be included in the DDR. In general, nutrient uptake is highest between the time of stand establishment and maturity. During establishment and approaching crop maturity, the uptake rates are often less than during the growth phase.

3.9 Storage for Spray Systems

The total storage volume required for land treatment systems consists of three (3) separate storage components such that:

Total Storage = *Operational Storage*
\+
Wet-Weather and Emergency Storage
\+
Water Balance Storage **eq. 3.9**

These separate storage components are described in the sections that follow.

3.9.1 Operational Storage for Spray Systems

Operational storage is a design parameter. For example, many land treatment systems are designed to apply wastewater 5 days per week and store weekend flows. Facilities that harvest cover crops on a frequent basis may stop irrigation to allow drying of the spray fields. Wastewater storage volume is required during these periods.

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3.9.2 Wet-Weather and Emergency Storage for Spray Systems

Wet-weather and emergency storage provides for periods when wastewater cannot be applied, i.e. excessive rainfall, saturated soil, equipment failure, etc. EPD has minimum requirements for wet-weather and emergency storage. These are necessary to ensure reliability of the slow-rate land treatment system.

The volume provided for wet-weather and emergency storage must be the greater of 12 days average design flow volume, or:

$$WW/E = \frac{\text{Delta } P \times (30.4 \text{ days/month})}{WLR_C} \qquad \textbf{eq. 3.9.2}$$

Where,	*WW/E*	=	Wet weather/emergency storage (days)
	Delta P	=	20-year variation from 5-year return monthly design precipitation (in). Reference Appendix, Section 6.3
	WLR_C	=	Wastewater loading rate in <u>most</u> critical water balance month (in/month). Reference Section 3.7.2

3.9.3 Water Balance Storage for Spray Systems

Water balance storage is a function of wastewater flow, wetted field area and the wastewater loading rate. Therefore, before the water balance storage volume can be determined, the actual, rather than design wastewater loading rate must be calculated. In order to calculate the WLR, the areas necessary to eliminate the operational, the wet-weather and emergency storage volumes, as well as, the area necessary to treat a normal week's flow at the design loading rate must be calculated. Once the WLR has been calculated, the required monthly water balance storage is determined from water balance calculations and the following equation:

$$WBS = WLR_A - WLR_D \qquad \textbf{eq. 3.9.3}$$

Where,	*WBS*	=	Required water balance storage (in/month)
	WLR_A	=	Hydraulic wastewater loading rate (in/month); assumes all influent wastewater is applied to the spray fields
	WLR_D	=	Design wastewater loading rate (in/month); Reference eq. 3.7.2

Example calculations of this type are presented in Appendix Section 5.4.7. Note that additional design measures may be required if groundwater mounding is the LDP. For example, a designer may build additional wet weather storage capacity into the design to avoid irrigation during periods of high natural groundwater recharge during and after increased rainfall (i.e. when excessive mounding might occur). Please see Section 3.15 for additional discussion of groundwater mounding.

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3.10 Storage for Drip Systems

3.10.1 Soil Storage Capacity for Drip Systems

It is important to consider the available water storage capacity in the soil column above the dripper lines. All of the permeability calculations used are based on a saturated condition. A properly operated drip system will maintain aerobic conditions and therefore tend to not be saturated most of the time. Potential problems with specific application rates include surfacing of wastewater within the drip fields. In an effort to prevent the potential for this type of malfunction, we have recommended a minimum burial depth of 8 inches. In addition, the soil storage capacity should be calculated to ensure that the minimum burial depth is adequate. The needed volume is approximately equal to one hour of flow for intermittent applications. Additional volume may be required for extended application periods.

In an effort to analyze the soil storage capacity, some definitions must first be outlined. They are:

Vp = pore volume.
Vw = water volume.
Mw = water mass.
Vs = solids volume.
Vt = total volume.
Mt = total mass.
Va = air volume.
Ms = solids mass.
Bulk density = Pb. Pb = Ms/Vt.
Particle Density = Pp. Pp = Ms/Vs = 2.65 gm/cm^3 (relatively constant).
Saturation ratio = S. S = Vw/Vp (degree of saturation = S x 100, expressed as a %).
Volumetric water constant = θ. θ = Vw/Vt.
Porosity = n. N = Vp/Vt = (1-Pb/Pp) = e/(1+e).
Effective porosity for storage volume = ne. ne = Va/Vt = n x (1-S).
Effective porosity for flow = nef. Nef = F x ne = F x n x (1-S).
Void ratio = e. e = Vp/Vs = n x (1-n).

The required depth can be calculated as follows:

Soil Storage Capacity = Φ. Φ = Va/Vt = n x (1-S) = n – θ.

$D = G\ (gal/hr) \div 7.48\ gal/ft^3 \div [F \times (1 - Pb/Pp) \times (1-S)]\ ft^3/ft^3 \div (L \times W)\ ft^2 \times 12\ in/ft$ **eq. 3.10.1**

Where:

D is the minimum soil depth required to store the wastewater applied in one hour without wastewater surfacing,

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L x W equals the spacing of the drip emitters and dripper lines,

F is a fraction less than one, and

G is the drip emitter discharge rate.

The soil is a very tortuous medium, far from containing a neat network of continuous, interconnected voids. To account for this tortuosity, the porosity must be reduced by a factor **F** to estimate the effective porosity flow or dynamic porosity. Two soils may have different *nef* depending on clay content and degree of aggregation. Depending on clay content, F is established as a maximum of 35%.

This provides the depth required per hour of application. For intermittent operations, one hour is considered a minimum for the purposes of this calculation (but not a minimum dose run time). If a surface application is selected, loadings should be the same as other surface irrigation systems to prevent runoff.

3.10.2 Storage Volume for Drip Systems

3.10.2.1 General

The total storage volume required for the subsurface drip systems will differ from typical LAS systems and the surface drip systems. Operational storage for cutting and harvesting is essentially eliminated for subsurface installations and wet weather storage, because of subsurface applications, is not a major factor. However, water balance storage and emergency storage are required. For automated systems, operations may occur for 24 hours per day, seven days per week. Some manual systems may only operate 5 days per week. Operational storage will be required to get surface drip installations and manually operated systems through the entire week. Emergency storage will be required to supplement for equipment malfunctioning. Wet weather storage requirements may result from severe weather causing completely saturated conditions. The Georgia EPD has established minimum requirements for wet weather and emergency storage to ensure the reliability of the treatment system. The volume provided for wet weather and emergency storage must be the greater of 3 days average design flow volume or as calculated in equation 3.10.2 of these guidelines. Water balance storage must be calculated in accordance with Section 3.10.3 of these guidelines. These minimum storage requirements may be increased based on the crop cover, water balance and reliability provided. For subsurface application, minimum emergency storage requirements are established at three (3) days unless 100% back-up reliability is provided, including standby power. Under no circumstances will less than 24 hours be provided.

Surface application minimum storage requirements are five (5) days. This minimum volume is necessary to ensure system reliability and provide wet weather and emergency storage. Water balance storage must also be determined. Surface drip systems should not be operated during rainfall events that produce run-off from the site. A water balance must be prepared to determine storage requirements as identified in Section 3.7 of these guidelines. Elements of the water balance include: allowable hydraulic loading, potential evapotranspiration, design percolation, and design precipitation. Storage requirements must be based on anticipated wet weather flows. Stormwater infiltration and inflow (I & I) must be included in the storage calculations.

3.10.2.2 Operational Storage for Drip Systems

Operational storage is a design parameter. For example, many wastewater irrigation systems are designed to apply wastewater 5 days per week and store weekend flows. Facilities with surface applications which harvest cover crops on a frequent basis may stop irrigation to allow drying of these fields. Wastewater storage volume is required during these periods.

3.10.2.3 Wet Weather and Emergency Storage for Drip Systems

Wet weather emergency storage provides for periods of excess rainfall, saturated soil, and equipment failure when wastewater cannot be applied. The Georgia EPD has minimum requirements for wet weather and emergency storage. These are necessary to ensure reliability of the slow rate land treatment system.

The volume provided for wet weather and emergency storage must be the greater of the required for the system (5 days surface, 3 days subsurface) days average design flow volume or the following:

[(Delta P)(30.4 days/month)]/D(allowed) crit **eq. 3.10.2**

Where:

Delta P = 20-year variation from 5-year return monthly design precipitation (in).

D(allowed) crit (in/mo) = Maximum allowable hydraulic loading in most critical water balance month.

Weather flow storage shall be based on a peak flow of ADF plus 25% ADF to account for I&I. Any sewer studies that have been performed for the community may be used to document actual anticipated wet weather flows.

3.10.3 Water Balance Storage for Drip Systems

Water balance storage is a function of wastewater flow, wetted field area and the wastewater loading rate. Therefore, before the water balance storage volume can be determined, the actual rather than design wastewater loading rate (WLR), in/week, must be calculated. In order to calculate the WLR, the areas necessary to eliminate the operational and the wet weather and emergency storage volumes as well as the area necessary to treat a normal week's flow at the design loading rate must be calculated. Once the WLR has been calculated, the required monthly water balance storage is determined from water balance calculations and the following equation:

WBS = D(potential) – D(allowed) **eq. 3.10.3**

Where:

WBS = Required water balance storage (in/month)

D(potential) = Potential wastewater loading (in/month); assumes all influent wastewater is applied to the drip fields

D(allowed) = Maximum allowable hydraulic wastewater loading (in/month); Reference eq. 3.7.2.

3.11 Determination of Wetted Field Area for Spray Systems

The wetted field area is subdivided into individual spray fields. Effluent is normally applied once per week per field. This allows for reaeration and drying of the soil profile. A 3-foot zone of aeration must be reestablished between wastewater applications.

The wetted field area is sized to adequately treat four volumes of water; the storage volumes discussed in Section 3.9 and seven days of the design average daily flow. In equation form, this relationship is represented as:

A(wetted) = A(ADF) + A(OP) + A(WW/E) + A(WBS) **eq. 3.11**

Where,	*A(wetted)*	=	required wetted field area (acres)
	A(ADF)	=	area (acres) necessary to treat seven days' average daily flows
	A(OP)	=	area (acres) necessary to treat the operational storage (ref. Sect. 3.9.1)
	A(WW/E)	=	area (acres) necessary to treat the wet weather/emergency storage (ref. Sect. 3.9.2)
	A(WBS)	=	area (acres) necessary to treat the water balance storage (ref. Sect. 3.9.3)

EPD requires that sufficient area be provided so that the operational storage, the wet weather and emergency storage, and the water balance storage can be eliminated within a 90-day period. The necessary areas for treating the operational and wet weather/emergency storage volumes are determined using the wastewater loading rates during the critical water balance month, WLR_C. The necessary area for treating water balance storage is determined using the actual wastewater loading rate, WLR_A. Calculation of each of the area elements is discussed in the following sections.

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3.11.1 Area for Average Daily Flow, A(ADF) for Spray Systems

The area necessary for distributing the average daily flow is calculated using the following formula:

$$A(ADF) = \frac{7\ days}{1\ week} \times \frac{ADF\ gal}{day} \times \frac{1\ cf}{7.48\ gal} \times \frac{1\ acre}{43{,}560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR_D,\ in} \qquad \textbf{eq. 3.11.1}$$

3.11.2 Area for Operational Storage, A(OP) for Spray Systems

The operational storage volume is to be eliminated within a 90-day period. The area A(OP) is based on the critical month WLR and is calculated using the following formula:

$$A(OP) = gal\ stored \times \frac{7\ days}{90\ days} \times \frac{1\ cf}{7.48\ gal} \times \frac{1\ acre}{43{,}560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR_C,\ in} \qquad \textbf{eq. 3.11.2}$$

3.11.3 Area for Wet Weather and Emergency Storage, A(WW/E) for Spray Systems

The wet weather and emergency storage volume is also to be eliminated within a 90-day period. Therefore, the equation for calculating A(WW/E) is the same as 3.10.2 with the wet weather and emergency storage volume substituted for the operational storage volume.

$$A(WW/E) = gal\ stored \times \frac{7\ days}{90\ days} \times \frac{1\ cf}{7.48\ gal} \times \frac{1\ acre}{43{,}560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR_C,\ in} \qquad \textbf{eq. 3.11.3}$$

3.11.4 Area for Water Balance Storage, A(WBS) for Spray Systems

The water balance storage is also to be eliminated within a 90-day period. The equation for calculating A(WBS) is similar to 3.10.2, with the water balance storage volume substituted for the operational storage volume, and the actual wastewater loading rate, WLR_A, substituted for the critical month, WLR_C.

$$A(WBS) = gal\ stored \times \frac{7\ days}{90\ days} \times \frac{1\ cf}{7.48\ gal} \times \frac{1\ acre}{43{,}560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR_A,\ in} \qquad \textbf{eq. 3.11.4}$$

Example calculations of the wetted field area requirements are contained in section 5.4.7.

3.12 Determination of Wetted Field Area for Drip Systems

The total wetted field area required for the drip irrigation system will be broken down into individual application fields which must be capable of being isolated and monitored. Effluent may be applied intermittently to any of the fields in any sequence that has been approved in the Operations Manual for the project. Intermittent or cyclic wastewater application on these systems is necessary to allow the restoration of aerobic conditions in the soil profile and maintenance of the infiltration capacity. The wetted field area is sized to adequately treat a combination of three volumes of water – seven days of the design average flow, emergency

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storage, and water balance storage. Since storage in the drip systems is minimal, sufficient area must be providing so that the flows stored can be eliminated within a 30-day period. If 20 or more days of total storage is provided, storage can be eliminated within a 90-day period. <u>If less than three days of storage are provided, the flows stored must be eliminated within 7 days.</u>

The wetted field area must be sized to adequately treat the storage volumes discussed and seven days of average daily design flow. In equation form this relationship is represented as:

$$A(wetted) = A(ADF) + A(OP) + A(WW/E) + A(WBS)$$

Where:

A(wetted) = Required total wetted field area (acres)

A(ADF) = Area (acres) necessary to treat seven days' average daily flows

A(OP) = Area (acres) necessary to treat the operational storage

A(WW/E) = Area (acres) necessary to treat the wet weather/emergency storage

A(WBS) = Area (acres) necessary to treat the water balance storage.

Sufficient area must be provided so that all of the storage can be eliminated within a seven (7) or thirty (30) day period depending on storage provided as discussed above. The necessary area for treating storage volume is calculated as follows:

$$A(ADF) = \frac{7\ days}{1\ week} \times \frac{ADF\ gal}{day} \times \frac{1\ cf}{7.47\ gal} \times \frac{1\ acre}{43560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR,\ in}$$

eq. 3.12.1

Drip field area necessary for the treating/storage associated with the facility operating less than seven days per week is included in the A(ADF) calculation. The total storage (sto.) required consists of operational, wet weather/emergency and water balance storage which are all calculated as follows:

For 7 days depletion:

$$A(sto.) = \frac{gal(sto.)}{7\ days} \times \frac{7\ days}{1\ week} \times \frac{1\ cf}{7.48\ gal} \times \frac{1\ acre}{43560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR,\ in}$$

eq. 3.12.2

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For 30 days depletion:

$$A(sto.) = \frac{gal(sto.)}{7\ days} \times \frac{30\ days}{1\ week} \times \frac{1\ cf}{7.48\ gal} \times \frac{1\ acre}{43560\ sf} \times \frac{12\ in}{1\ ft} \times \frac{1\ week}{WLR,\ in}$$

eq. 3.12.3

Therefore, this calculation must be performed at least three times to find the total area required to eliminate the wastewater generated. One for Operational Storage, (A(OP), one for wet weather/emergency storage, A(WW/E), and one for water balance storage, A(WB). The total wetted land area is calculated as previously shown.

3.13 Buffer Zones, Public Access, and Protection of Water Supply Wells

3.13.1 Buffer Zones

Buffer zones should be maintained by forest, shrubs, or other screening vegetation. Rights-of-way can be used as part of the buffer area. However, these rights-of-way must be exclusive with no possibility of development.

3.13.1.1 Buffer Zones for Spray Systems

The following minimum buffer zones must be provided for all land treatment systems utilizing spray irrigation, which are required to protect the public from aerosol sprays:

a. A 150-foot buffer must be maintained between the edge of the wetted field area and all property lines.

b. A 300-foot buffer must be maintained between the wetted field area and any habitable structure.

c. A 150-foot buffer must be maintained between the edge of the wetted field area and any internal and external public roads.

d. Internal roads that are closed to public use do not require buffer zones. However, spray irrigation on these roads is prohibited.

e. A 100-foot buffer is required between the wetted edge of spray fields and the edge of any perennial lake or stream. A 50-foot buffer is required between spray fields and any intermittent watercourse. If wastewater application causes an intermittent watercourse to become perennial, the 100-foot buffer requirement will then apply.

f. A 150-foot buffer must be maintained between the property line and any part of the pre-application treatment facility and storage pond.

g. A 300-foot buffer must be maintained between any habitable structure and any part of the pretreatment facility and storage pond.

h. In no case shall a spray irrigation system be located within 300 feet of a drinking water well.

When deemed necessary by EPD, buffer zone requirements may be increased or added based on site-specific conditions.

3.13.1.2 Buffer Zones for Drip Systems

The following minimum buffer zones must be provided for all land treatment systems utilizing drip irrigation:

a. A 25-foot buffer must be maintained between the edge of the subsurface piping and the property line. A minimum 50-foot buffer must be maintained between the edge of the surface piping and the property line. This requirement is subject to change as a result of site topography and the flushing system provided.

b. A 50-foot undisturbed natural vegetative buffer is required between the drip piping and the edge of any perennial lake, or stream. A 25-foot undisturbed natural vegetative buffer is required for an intermittent watercourse. If application of wastewater causes an intermittent watercourse to become perennial, a 50-foot buffer requirement will apply. All buffer requirements for trout streams and sedimentation and erosion control will also apply. Any local ordinances or requirements more stringent will govern.

c. A 300-foot buffer must be maintained between any habitable structure and any part of the onsite pretreatment and storage facility. This requirement does not apply to the underground septic tank interceptor tanks. Septic tanks must be installed in accordance with the local health department requirements.

d. A 150-foot buffer must be maintained between the property line and any part of the pre-application treatment facility and storage pond.

e. In no case shall a drip irrigation system be located within 300 feet of a drinking water well.

When deemed necessary by EPD, buffer zone requirements may be increased or added based on site-specific conditions.

3.13.2 Public Access

Public access to the irrigation fields should be discouraged by posting signs and maintaining well-vegetated buffer zones. Fencing of irrigation fields in remote areas is usually not required.

However, fencing and access road gates should be provided along property lines adjacent to residential and other developed areas. Fencing is required at pre-application treatment facilities, pump stations, and holding ponds. The permittee is required to maintain fencing and signage in a condition that will deter reasonable efforts to enter the site.

3.13.3 Protection of Water Supply Wells

The potential effect of a land treatment system on a water supply aquifer is site-specific and difficult to predict. The following minimum buffer zones must be provided for all land treatment systems utilizing drip and spray irrigation:

a. In no case shall an irrigation system be located within 300 feet of a drinking water well (permitted or unpermitted).

b. Beyond 300 feet, the requirements for buffer areas in relation to potable water wells will be determined on a case by case basis.

c. Abandoned wells [as defined by O.C.G.A. 12-5-134 (6)] within the treatment site must be identified in addition to all public and private potable water supply wells within 2500 linear feet (L.F.) of the land treatment site. All potable wells within 2500 L.F. must be shown on a 1:24,000 scale USGS Topographic Quadrangle Map depicting the application area boundaries and designating each well as public or private. For all public wells within 2500 L.F., the DDR must list their permit numbers.

Wellhead Protection requirements may increase the buffer distances as necessary. The hydrogeological evaluation must clearly show (through an evaluation of the depth of the water supply aquifer, its gradient, the condition of the aquitard, the condition of existing potable water supply wells and their capacity, groundwater pollution susceptibility and groundwater recharge maps, and/or any other relevant hydrogeological information) that the LAS will not have any effect on those wells. Abandoned, shallow and/or poorly constructed potable wells within 500 feet of the land treatment system must be properly filled, sealed, and plugged by a water well contractor licensed by the Water Well Standards Act Council according to the Water Well Standards Act (O.C.G.A. 12-5-2- et. seq.).

3.14 Surface Drainage and Runoff Control

Drainage of stormwater runoff should be considered in design. All irrigation fields must be protected against flooding, ponding, and erosion. Stormwater runoff from upgradient areas should be channelized through or around the site. However, the collection and channelization of irrigated wastewater must be avoided. Direct application of wastewater to drainage ditches and seasonal watercourses is prohibited.

A properly designed and operated slow-rate land treatment system will not produce direct runoff or surface flow; i.e., all water applied will either evaporate or infiltrate into the soil profile. Sites that experience direct runoff, surface flow, or a wet surface as a result of wastewater application will be required to reduce hydraulic loading rates. Areas exhibiting any of the preceding conditions on a regular basis must be eliminated from future applications, unless corrected. A reassessment of the design should be performed to determine if reconstruction or repair of the failing area would correct the deficiency. Any areas taken out of service because of failure will subsequently cause a reduction in the permitted system capacity.

Water resulting from line flushing must be dispersed over a wide area. No flush waters shall be permitted to flow off the site onto adjoining property. Direct discharge of these flows into any water course is prohibited. Effluent from line flushing should be absorbed by the surrounding area within a few minutes of line flushing. Line flushing should not be performed during any rain event.

Indirect runoff as a result of interflow, defined aslateral unsaturated flow, changes in slope, and shallow restrictive soil layers can be expected at some land treatment sites. Indirect runoff is acceptable when it is dispersed over a wide area, but it still may warrant stream monitoring. Note that interflow (as unsaturated flow) is not considered groundwater (which is discussed in the next section).

3.15 Subsurface Drainage and Groundwater Mounding

Sites with a seasonal high water table less than 5 feet from the surface will not be accepted for slow-rate land treatment unless an extensive mounding analysis is provided to demonstrate that the three foot separation requirement will be maintained. It is necessary to maintain an adequate vertical separation (minimum of 3 feet) between the applied waste (ground surface if applied to the ground) and the altered or mounded seasonal high groundwater table (or a perched aquifer, if it exists, or if increased recharge below the LAS creates one), in order to facilitate soil remediation effects of the applied waste. The “altered or mounded” term is meant to signify the additive or compounded effects of the disposal activity onto the ambient seasonal high groundwater table (or perched aquifer). Steep slopes and/or shallow confining or semi-confining lithologies such as clay, silt, or bedrock, especially when they underlie highly-permeable surface soils, may contribute to groundwater mounding. Any groundwater mounding is regarded as excessive if it has undesirable effects, which may include (but are not necessarily limited to):

a. A groundwater rise that is high enough to compromise the effectiveness of treatment (as discussed above),

b. A groundwater breakout or discharge where the mounded water table intersects a slope (i.e. side-slope seepage), or

c. Ponding or pooling.

A groundwater mounding analysis (i.e. predictive calculations or modeling methods) may be necessary to determine whether groundwater mounding attributable to increased groundwater recharge from the LAS is a LDP, (i.e. whether the likelihood of excessive groundwater mounding warrants a lower application rate limit than standard factors such as soil drainage and nutrient uptake would normally indicate, and if so, how much of a reduction would be necessary). Guidance by the Colorado School of Mines, hereinafter, "CSM guidelines," (Poeter et. al., 2005) contains a useful decision tool for a preliminary mounding analysis to determine whether site conditions indicate a high potential for excessive groundwater mounding, whether further mounding analysis is required, and (if so) the level of effort required to complete it. The CSM guidelines identify some of the applicable analytical and numerical groundwater mounding models that can be used either to rule out excessive groundwater mounding or to prevent excessive mounding through proper system design and/or operation. In using these calculations, the duration of infiltration should be the expected duration of planned site operations in years. The CSM guidelines and U.S. Geological Survey Scientific Investigations Report 2010-5102 (Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins) contain spreadsheets for mounding calculations based on the Hantush (1967) analytical model (a well-accepted analytical model). However, any ground water mounding analysis may be used as long as the input parameters and the method of analysis consider all of the significant hydraulic conditions at the analyzed site.

If the project is located in one of the counties identified on Figure 3.15.1 below, extensive soil investigations and mounding analysis will be expected to demonstrate that a three foot separation between the applied waste and the mounded seasonal high water table is always maintained.

See Figure 3.15-2 below for a representation of how groundwater mounding can occur due to rapid and excessive infiltration at a site.

Figure 3.15-1
COUNTIES WITH LOCALLY SEASONAL HIGH WATER TABLE

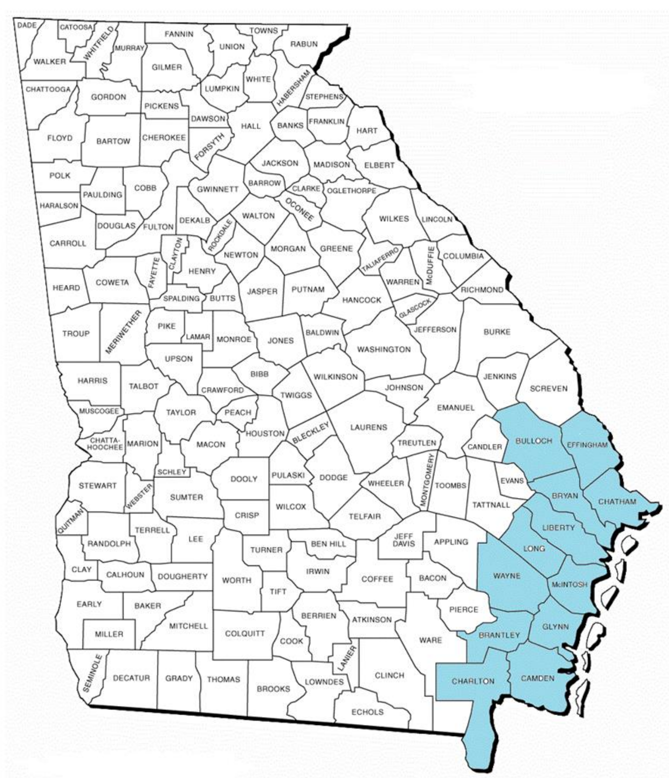

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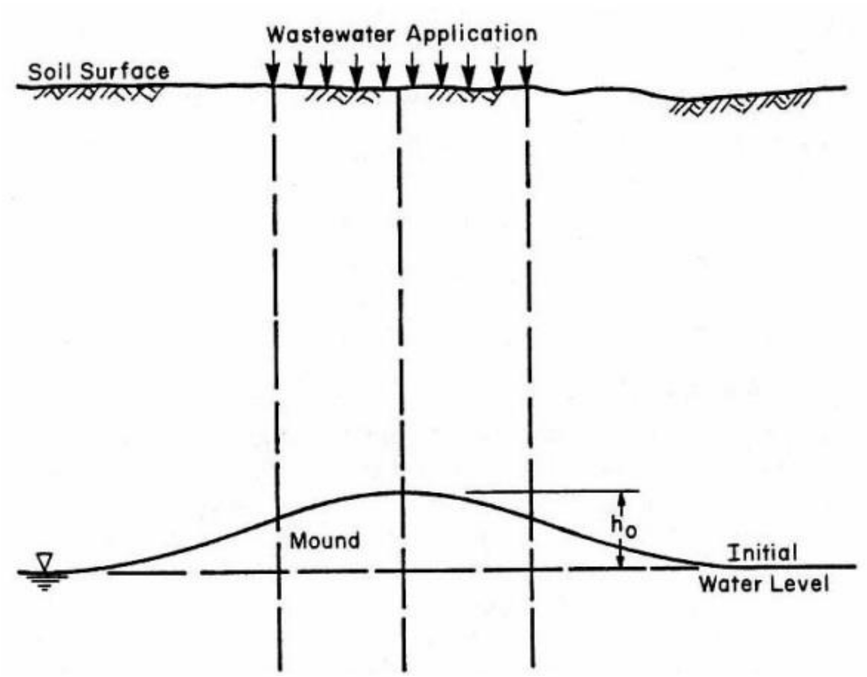
Figure 3.15-2
GROUNDWATER MOUNDING (EPA 2006)



3.16 <u>Distribution Systems and Construction</u>

3.16.1 General

Hydraulic calculations for the pump and distribution system must be submitted with the plans and specifications. Irrigation field pressure and flow variation due to friction loss and static head for solid set, uniformly spaced systems should not exceed +/-10 percent of the design nozzle/emitter pressure or flow. If this criterion cannot be met, revisions to field layout, spray/emitter output, or any other viable option should be used to comply with this requirement. The system will not be allowed to initiate operations if the total flow or pressure variation is in excess of 10% of the design. The 10% difference should be the difference between any two nozzles/emitters in the entire system.

<u>IMPORTANT</u>: The irrigation fields must be laid out so that the irrigation lines generally follow the contours of the site. The engineer must visit the site when the contractor is laying the lines out to verify that they do follow the contours and that the appropriate buffer is maintained from intermittent streams, including drainage ways that may not have been apparent from the topographical map(s) used to design the system. Surface application irrigation systems shall be designed and operated to ensure uniform hydraulic loading (+/- 20%) across the system or across areas of similar soil types (if different hydraulic loading rates are used for different design parameters for areas of a spray system based on soil type).

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The DDR should contain the proposed line layout so that flushing flows and static head calculations can be addressed on a field by field basis. Each field should define total flow (gpm) proposed, total length of piping, nozzle/emitter spacing, line spacing, total number of lines and total number of lines to be included per flushing. This layout information should be shown on a topographic map. All proposed main line sizes and lengths along with individual irrigation line lengths should be shown. All return piping sizes and lengths should also be shown and should not exceed manufacturers' specifications to ensure equal distribution to each nozzle/emitter. Nozzle/emitter and line spacing should be in accordance with manufacturers' recommendations.

The Operations Manual should address disinfection and flushing of lines to prevent solids buildup. Flushing of lines should be performed according to the manufacturers' recommendations but at a minimum on a bi-monthly basis. Velocities must be a minimum of 2 feet per second at the distal end of irrigation or return line during the flushing operation. Calculations supporting the 2 feet per second should be included in the DDR.

For spray systems, neither secondary mist nozzles on impact sprinklers nor PVC risers may be used. Secondary mist nozzles saturate the ground around the sprinkler riser and undermine the riser's support, and they make it impossible to inspect operating sprinklers without getting wet. EPD recommends that flexible connections be used to connect the spray system risers to the distribution line.

Satisfactory operation of the irrigation system is necessary to safeguard the health of the public and to ensure that the wastewater effluent is disposed of in an environmentally sound manner. For drip systems, emitter manufacturers must supply documentation that placing the emitter in the root zone of the cover crop will not interfere with the emitter performance. Emitters should be buried no less than 8 inches nor more than 12 inches from the surface for optimum nutrient uptake. Variance from this depth of burial will be evaluated on a case by case basis if supported by manufacturers' recommendations.

3.16.2 Access, Flow Measurement, and Controls

The layout of irrigation fields and irrigation field roads should provide easy access for inspection and maintenance of the distribution system. Control valves should be installed so that they are readily accessible for maintenance and replacement (i.e., either above ground or in a valve pit). We recommend cast iron valve boxes with concrete collars. In addition to control valves for each field, we highly recommend installation of a shut-off valve for each lateral and each sprinkler. Experience has shown that such valves will expedite maintenance of the system. Taps located near the most distant sprinklers must be provided in each field so pressure gauges can be easily used to verify operating pressures and to locate pressure losses. Irrigation field access roads must be designed for all-weather use. Steep grades should be avoided. Irrigation on access roads is prohibited.

A flow-totalizing recorder is required on the discharge of each irrigation pump station to measure the volume of wastewater applied to the irrigation fields.

A low-pressure detection system (with sensors in each field for large systems) must be provided to automatically shut down irrigation pumps in the event of force main, submain, or lateral blowout. Similarly, a high pressure shut-off at the irrigation pumps must be provided. In conjunction with these systems there must be an indicator alarm or an auto-dialer that alerts the operator of an early pump shutdown. Depending on the operational control system for the fields, automatic shut-off controls for high intensity rainfall and/or high wind speeds (spray systems) may be required.

Monitoring equipment must be provided to detect a +/- 5% change in flow rate to any given field. If a change is detected which shows a +/- 10% variance, evaluations must be performed to determine if it is a result of clogging filters, force main breaks, nozzle/emitter clogging, leaks in field lines, a flush valve failure, etc. The Operations Manual should address what actions are required to correct any such problem should it occur. Pumping equipment must be provided with pressure and flow sensitive controls which will disengage pumps if a +/- 10% variance in flow is detected.

3.16.3 Freeze Protection

EPD requires that aboveground piping systems should drain when depressurized. Pipe drains should discharge either to the irrigation fields or to the storage pond(s) and must not produce runoff.

3.16.4 Construction Disturbance, System Start-up and Testing

Construction activities associated with distribution systems can greatly alter the infiltration rate of irrigation field soils. Construction disturbance within irrigation fields must be kept to an absolute minimum. Excessive compaction of surface soils by construction equipment must be avoided. Where land clearing is a part of the construction, final permeability testing must be performed and the permeability must not change more than 15%. The permitted capacity of the system may be decreased by EPD if the permeability is significantly reduced.

Regrading of pipeline trenches must match original contours. Subsidence of trench backfill must be repaired, as this promotes channelization of runoff and erosion. Cuts or benches on slopes are not permissible. These disturbances intercept shallow, subsurface flow also promoting channelized runoff and erosion.

In forested systems, it is necessary to grub only the pipe centerline. Excessive clearing and grubbing should be avoided. Clearing for aboveground piping systems should involve only vegetation that will interfere with operation of the system. All areas disturbed by construction must be re-vegetated immediately. Areas in which seedlings are to be planted must have a cover crop of grass provided during the first three years following planting of the seedlings.

IMPORTANT: Before seeding or sprigging grass or ground cover in all areas of fields disturbed by construction, the land should be plowed to a depth of 16 inches with chisel plows.

Sloped areas may require protection from erosion. The *Manual for Erosion and Sedimentation Control in Georgia*, published by the State Soil & Water Conservation Committee, should be used as a guide for erosion and sedimentation control during construction of land treatment systems.

Pressure testing of the irrigation force mains and laterals must be conducted during installation to avoid damage to irrigation fields from re-excavation and repair. Extensive flushing is usually necessary to clear distribution system pipes of materials that may clog sprinkler nozzles. Care should be exercised to prevent erosion or flooding of the irrigation fields during pipeline flushing. Every effort should be made to keep trash and debris out of the distribution system. Sprinklers/emitters and drain valves should be checked for proper operation prior to installation.

Bare soil resulting from construction can tolerate only short periods of surface wastewater application before producing runoff. Surface irrigation of bare soil compacts the soil surface, reduces the infiltration rate, promotes erosion, and hinders the establishment of vegetation. In addition, the treatment capacity of bare soil is poor. Wastewater irrigation on bare soil is not allowed beyond what is necessary to establish a vegetative cover. Wastewater application at the design rate can begin only when a uniform vegetative cover has been established. Specifications for irrigation field construction must include a re-vegetation performance standard and this standard must be enforced.

EPD recommends that irrigation fields be developed before pre-application treatment facilities are constructed. This allows time for a vegetative cover to be reestablished on construction-disturbed areas. Potable, ground, or surface water should be used for distribution system testing and irrigation to establish vegetation. Since one to three growing seasons may be required before newly constructed irrigation fields can accept the design wastewater loading, this start-up period must be considered in the design and operation of land treatment systems.

4.0 GUIDELINES AND CRITERIA FOR SITE MANAGEMENT

4.1 Operation and Management of Slow-Rate Land Treatment Systems

As discussed in Section 2.3, the facility's LAS Permit will require the owner or owner's engineer to write an Operations Manual (OM). This manual covers operation of both the irrigation fields and pre-application treatment facility. It provides a management scheme consistent with the basis of design outlined in the DDR. An outline for the scope of the OM Manual is presented in Appendix Section 5.1. The OM should be available on site at all time and updated as needed to ensure proper operation of the pretreatment facility and irrigation fields.

4.2 Monitoring Requirements

4.2.1 General

There are two objectives for a monitoring program at a land application site. The first is to satisfy the permit requirements set by EPD. The second objective is to provide the data necessary to optimize the system's operation. The data to meet the second objective may or may not be the same as that required by the permit. The facility's OM should address the data needs for optimum plant operation.

4.2.2 Pre-application Treatment Facility and Storage Pond(s)

Influent to the pre-application treatment system and/or treated effluent applied to the irrigation fields must be monitored. Parameters which may require monitoring under the system's permit include: influent flow, volume of water applied to the irrigation fields, BOD (influent & effluent), suspended solids (influent & effluent), fecal coliform bacteria, pH (influent & effluent), ammonia nitrogen, nitrate nitrogen, total Kjeldahl nitrogen, total phosphorus, chloride, Na, K, Ca, Mg, metals, priority pollutants, and primary and secondary drinking water MCLs. The parameters included in the permit monitoring requirements and the sampling frequency for those parameters will be determined on a case-by-case basis and will be dependent on site conditions.

4.2.3 Groundwater

A system is required for monitoring the quality of groundwater influenced by the land treatment system. Groundwater leaving the irrigation site at the site boundaries must meet primary and secondary drinking water standards.

Subsurface geology, the direction of groundwater flow, any changes in the direction of groundwater flow anticipated by a groundwater mounding model (if applicable), and the need to detect potential excessive groundwater mounding (if applicable) determine the placement and depth of monitoring wells. EPD recommends the development of a groundwater potentiometric surface map prior to startup of the facility. Minimum monitoring well requirements are as follows:

a. One well upgradient or otherwise outside the influence of the land treatment site for background monitoring.

b. One well within the wetted field area of each drainage basin (perennial and intermittent) intersected by the land treatment site.

c. Two wells downgradient of the wetted field area in each drainage basin intersected by the land treatment site. Downgradient wells will be considered compliance points and must be located within 50 ft. of the wetted perimeter of the application site(s).

d. Larger sites or sites with complicated surface and/or groundwater drainage may require additional monitoring wells.

e. All monitoring wells must extend to sufficient depth to sample seasonal fluctuations of the unconfined water table. Wells must not extend through confining layers.

f. Monitoring wells must be provided with casings and screens. The casing must be backfilled and sealed to prevent entry of surface water. This seal should include a concrete apron surrounding the well at the surface. Care should be taken to avoid contamination of wells both during and after construction.

g. **IMPORTANT**: Monitoring wells must be numbered and locked.

h. Monitoring wells should follow a labeling convention that utilizes a U, M, and D designation for upgradient, midfield, and downgradient well locations, respectively.

EPD suggests that monitoring well construction conform to the *Manual for Groundwater Monitoring*, as amended, which was developed as a reference for the design and construction of groundwater monitoring wells at slow-rate land treatment systems (see Figure 4.2-1). Additional sources for well installation guidance include ASTM Standard D5092, *Standard Practice for Design and Installation of Ground Water Monitoring Wells* and USEPA Science and Ecosystem Support Division's *Design and Installation of Monitoring Wells*.

Monitoring of the groundwater under the LAS permit may require measurement of one or more of the following parameters: depth to groundwater, pH, nitrate nitrogen, total phosphorus, electrical conductivity, chloride, fecal coliform bacteria, metals and priority pollutants. At any site where water level monitoring is required for the purpose of calculating groundwater elevations and constructing a potentiometric map (not merely to calculate well purge volumes during sampling), or where groundwater mounding is a LDP, the facility should measure water levels and survey the well top-of-casing elevations to a precision of 0.01 ft. The parameters included in the permit monitoring requirements and the sampling frequency for those parameters will be determined on a case-by-case basis and will be dependent on site conditions.

EPD recognizes the installation and monitoring of soil water lysimeters within the wetted field area as a useful trend monitoring device to identify problems before the groundwater system is affected.

4.2.4 Surface Water and Drainage Systems

When a perennial stream traverses or lies at the boundary of a slow-rate land treatment site, water quality monitoring of this stream may be required. The parameters and frequency of monitoring will be specified as a condition in the facility's LAS Permit. Sampling upstream and downstream of the wetted field area as well as flow measurement may also be required.

Land treatment systems incorporating drainage improvements that result in a point discharge to surface waters must apply for a National Pollutant Discharge Elimination System (NPDES) Permit. In addition to requiring an OM, the NPDES Permit will include effluent limits, monitoring parameters, and sampling frequencies for the drainage system. The intent of this monitoring is to ensure complete renovation of the irrigated wastewater before discharge.

4.2.5 Soil

Representative soil samples from each major soil series within the wetted field area must be taken and analyzed according to requirements in the facility’s LAS permit. In particular, soil pH is an indicator of changes in soil chemistry. If the soil pH changes significantly, additional analyses may be required.

Land treatment systems receiving direct or indirect industrial process wastes may be required to monitor metals, salts, and priority pollutants in site soils and possibly vegetation. The parameters and frequencies will be determined on a case-by-case basis.

4.2.6 Rainfall and Climatic Data

Monitoring of daily rainfall at the land application site is required. Antecedent precipitation and soil moisture conditions can be correlated to provide an operating scheme for the system. Monitoring of wind speed and direction may also be required.

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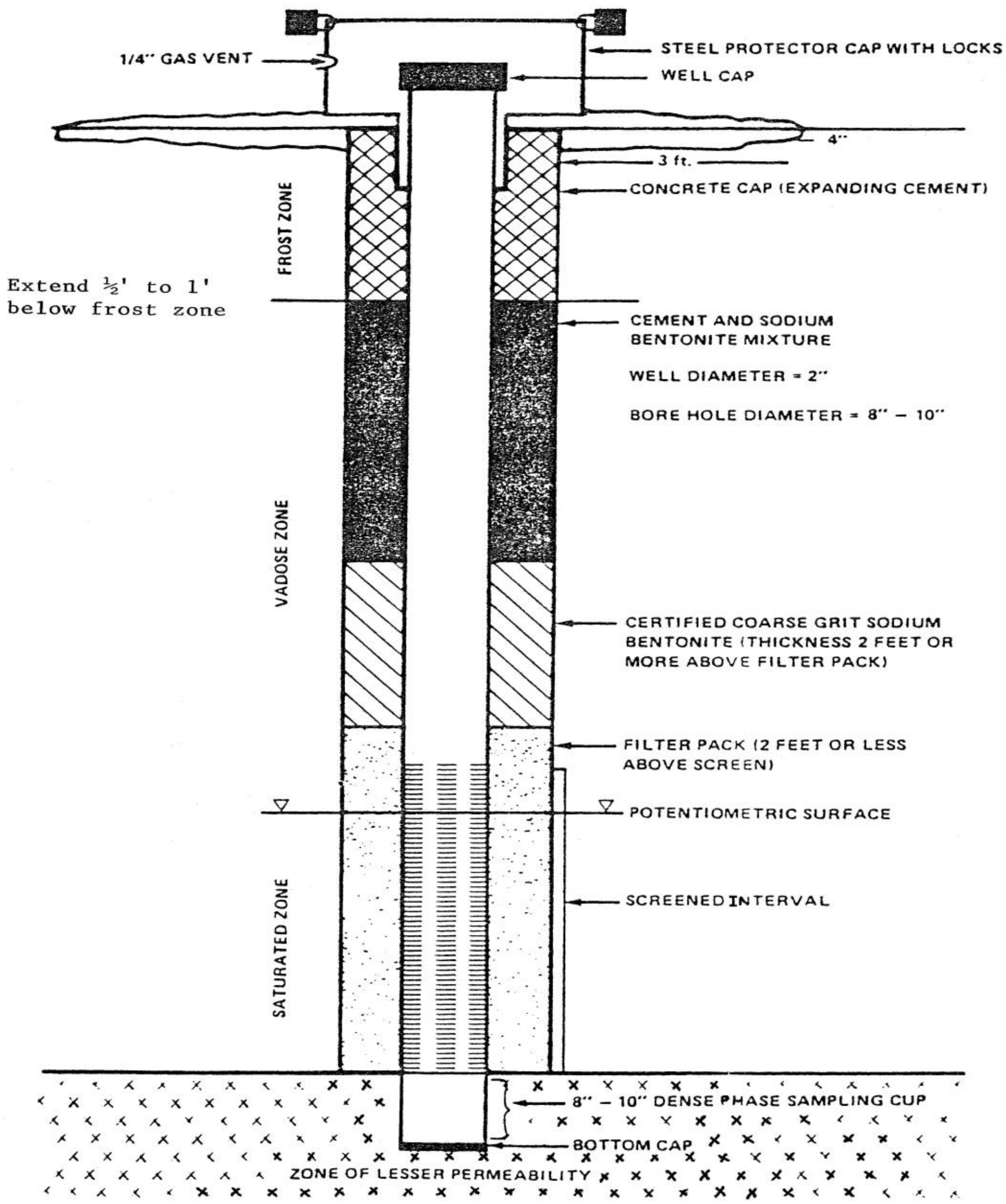
Figure 4.2-1
GENERAL MONITORING WELL – CROSS SECTION



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5.0 APPENDICES

5.1 Operations Manual for Slow-Rate Land Treatment Systems

The manual should include, but not be limited to, the following:

5.1.1 Introduction

a. System Description:
   1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, pre-application treatment system, and irrigation fields.
   2. A map of the land treatment facility showing the pre-application treatment system, storage pond(s), irrigation fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.
   3. A map of interceptor sewers, force mains, and major pump stations tributary to the land treatment facility. Indicate their size and capacity.
   4. A schematic and plan of the pre-application treatment system and storage pond(s) identifying all pumps, valves, and process control points.
   5. A schematic and plan of the irrigation system identifying all pumps, valves, gauges, sprinklers, etc.
   6. For any/all maps, a graphical scale, north arrow, and appropriate source references for any map content.

b. Discuss the design life of the facility and factors that may shorten its useful life. Include procedures or precautions that will compensate for these limitations. For sites where groundwater mounding is a LDP, include a detailed description of any monitoring, operational, or design mechanisms necessary to detect or prevent excessive groundwater mounding.

c. A copy of the facility's Land Application System (LAS) Permit, and/or National Pollutant Discharge Elimination System permit, if applicable.

5.1.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:
   1. Describe the various job titles, number of positions, qualifications, experience, training, etc.
   2. Define the work hours, duties and responsibilities of each staff member.

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5.1.3 Facility Operation and Management

a. Pre-application Treatment System:
   1. Describe how the system is to be operated.
   2. Discuss process control.
   3. Discuss maintenance schedules and procedures.

b. Irrigation System Management:
   1. Wastewater Application. Discuss how the following will be monitored and controlled. Include rate and loading limits.
      a. Wastewater loading rate (inches/week)
      b. Wastewater application rate (inches/hour)
      c. Irrigation field application cycles
      d. Organic nitrogen and phosphorus loadings (lbs/acre/month, etc.)
   2. Discuss how the system is to be operated and maintained.
      a. Storage pond(s)
      b. Irrigation pump station(s)
      c. Irrigation field force main(s) and laterals
   3. Discuss start-up and shutdown procedures.
   4. Discuss system maintenance.
      a. Equipment inspection schedules
      b. Equipment maintenance schedules
   5. Discuss operating procedures for adverse conditions.
      a. Wet weather
      b. Freezing weather
      c. Saturated soil
      d. Excessive winds
      e. Electrical and mechanical malfunctions
   6. Provide troubleshooting procedures for common or expected problems.
   7. Discuss the operation and maintenance of back-up, stand-by, and support equipment.

c. Vegetation and Nutrient Management Plan (NMP):
   1. Discuss how the selected cover crop is to be established, monitored, and maintained.
   2. Discuss cover crop cultivation procedures, harvesting schedules, and uses.
   3. Discuss buffer zone vegetative cover and its maintenance.
   4. Discuss winter overseeding requirements
   5. Discuss supplemental nutrient requirements

d. Drainage System (if applicable):
   1. Discuss operation and maintenance of surface drainage and runoff control structures.
   2. Discuss operation and maintenance of subsurface drainage systems.

5.1.4 Monitoring Program (reference Section 4.2)

a. Discuss sampling procedures, frequency, location, and parameters for:
   1. Pre-application treatment system.
   2. Irrigation System:
      a. Storage pond(s)
      b. Groundwater monitoring wells (Note that at any site where water level monitoring is required for the purpose of calculating groundwater elevations and constructing a potentiometric map [not merely to calculate well purge volumes during sampling], the facility should measure water levels and survey the well top-of-casing elevations to a precision of 0.01 ft.)
      c. Drainage system discharges (if applicable)
      d. Surface water (if applicable)

b. Discuss soil sampling and testing.

c. Discuss ambient conditions monitoring:
   1. Rainfall
   2. Wind speed
   3. Soil moisture

d. Discuss the interpretation of monitoring results and facility operation:
   1. Pre-application treatment system.
   2. Irrigation fields
   3. Groundwater (Provide for the evaluation of long-term trends in downgradient well nitrate concentrations, to detect any increasing trends reflective of poor or diminishing system performance.)
   4. Soils

5.1.5 Records and Reports

A. Discuss maintenance records:
   1. Preventive
   2. Corrective

B. Monitoring reports and/or records should include:
   1. Pre-application treatment system and storage pond(s).
      a. Influent flow
      b. Influent and effluent wastewater characteristics

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2. Irrigation System
   a. Wastewater volume applied to irrigation fields
   b. Irrigation field scheduling
   c. Loading rates
3. Groundwater Depth (Include depth measurements to a precision of 0.01 ft., as applicable)
4. Drainage system discharge parameters (if applicable)
5. Surface water parameters (if applicable)
6. Soils data
7. Rainfall and climatic data

5.2 Thornthwaite Potential Evapotranspiration

The Thornthwaite Potential Evapotranspiration (P.E.T.) is defined as "the amount of water which will be lost from the surface completely covered with vegetation if there is sufficient water in the soil at all times for use of the vegetation." The Thornthwaite Method is an empirical equation developed from correlations of mean monthly air temperature with evapotranspiration from water balance studies in valleys of the east-central United States, where soil moisture conditions do not limit evapotranspiration (The Irrigation Association, 1983, pp. 112 to 114). The Thornthwaite method is applicable to slow-rate land treatment systems in the southeast United States, including Georgia. It is not applicable to arid and semi-arid regions west of the Mississippi River.

The Thornthwaite equation is outlined below. Note that the results are expressed in inches (in) for a 30-day month. The P.E.T. results must be modified by the actual number of days in each month. Finally, for water balance calculations as described in Section 3.7, a 30-year record of historical climatic data (referred to as the climatological normal) is required to determine monthly temperature normals used in the Thornthwaite equation.

$$\text{P.E.T.} = 1.6 \times Ld \times [(10 \times T)/I]^{A} \times (1\text{in} / 2.54\text{ cm})$$ **eq. 5.2.1**

Where,	P.E.T.	=	30-day Thornthwaite Potential Evapotranspiration (in)
	Ld	=	Daylight hours in units of 12 hours (reference Table 5.2-1)
	T	=	Mean (normal) monthly air temperature in degrees Celsius
	I	=	Annual heat index obtained by summing the 12 monthly heat indexes, i, where: $i = (T/5)^{1.514}$
	A	=	Power term derived from annual heat index, I, where: $A = 0.000000675(I)^3 - 0.0000771(I)^2 + 0.01792(I) + 0.49239$

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Table 5.2-1
MONTHLY AVERAGE DAYLIGHT HOURS AS A FUNCTION OF LATITUDE

	Daylight (x 12 hours)[a]	
Month	at 30º Latitude	at 35º Latitude
January	0.90	0.87
February	0.87	0.85
March	1.03	1.03
April	1.08	1.09
May	1.18	1.21
June	1.17	1.21
July	1.20	1.23
August	1.14	1.16
September	1.03	1.03
October	0.98	0.97
November	0.89	0.86
December	0.88	0.85

[a] Values for sites between 30 and 35 degrees latitude should be interpolated.

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5.3 Delta P Values for Georgia Climatic Divisions

Table 5.3-1
DELTA P VALUES FOR GEORGIA CLIMATIC DIVISIONS
(Reference Figure 5.3-1)

Georgia Climatic Division	Delta P [a] (inches)
Northwest	2.0
North Central	2.5
Northeast	3.0
West Central	2.5
Central	2.0
East Central	2.0
Southwest	2.5
South Central	3.0
Southeast	2.5

[a] 20-year variation from 5-year return monthly precipitation. Derived from National Oceanic and Atmospheric Administration historical rainfall data for Georgia.

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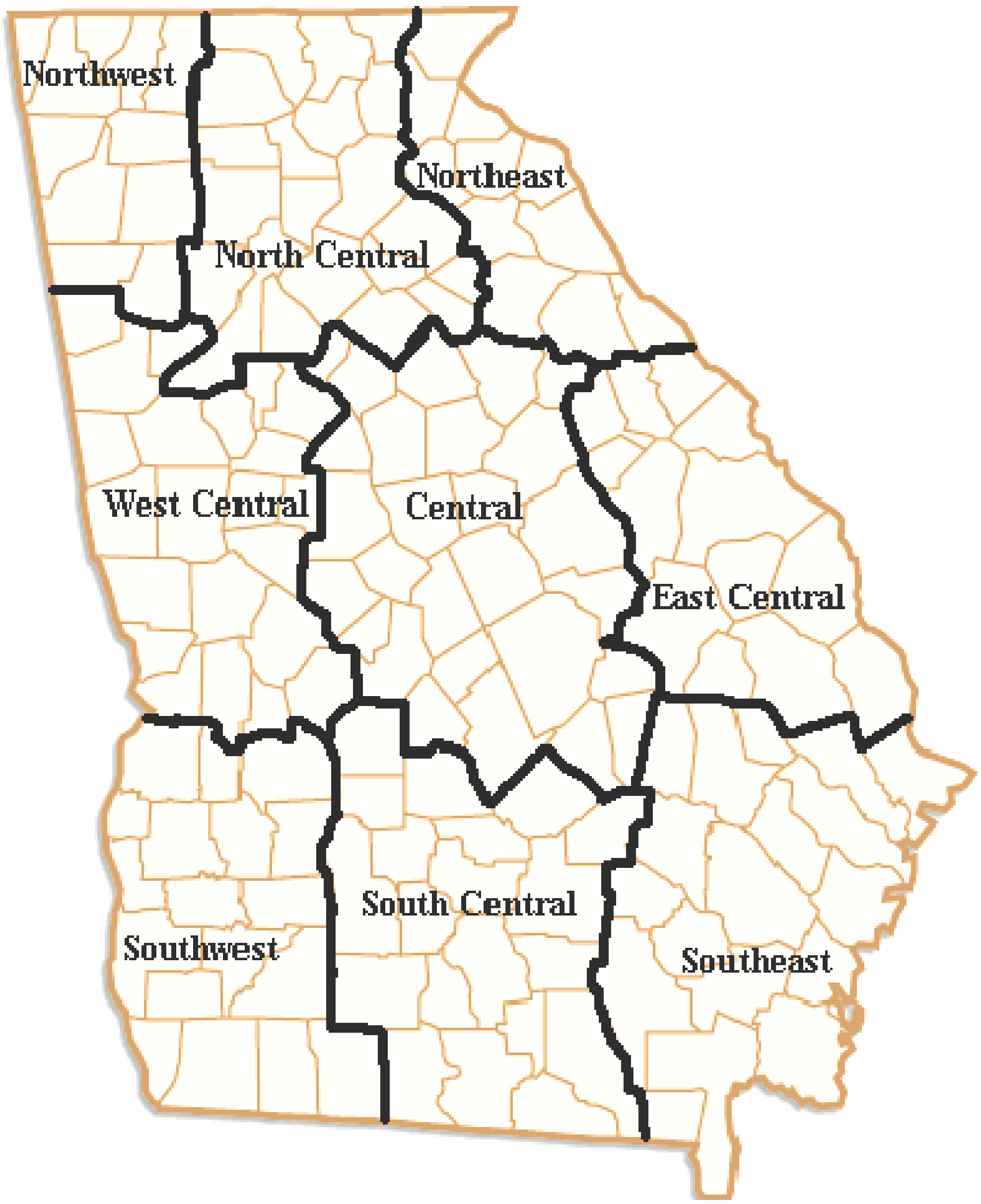
Figure 5.3-1
GEORGIA CLIMATIC DIVISIONS



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5.4 Spray System Example Calculations

5.4.1 Introduction and Assumptions

Design of slow-rate land treatment systems is a process of balancing site limitations against construction and operating costs. The following example calculations are for a hypothetical 4-MGD facility in the North Central Piedmont area of Georgia. They illustrate the basic computations required and the relationship between variables.

The following assumptions were made. They must not be used for real world systems without verification.

a. The average design flow is 4.0 MGD with a daily peak factor of 2 and a weekly peak factor of 1.25.

b. The land treatment site is moderately well drained with seasonal high groundwater more than 5 feet below the surface. The most limiting layer in the soil profile occurs at a depth of 2 to 4 feet. Testing for saturated vertical hydraulic conductivity indicates an average permeability for this layer of 0.00015 cm/s corresponding to 0.213 inches/hour.

c. The annual average precipitation is 49 inches. Evapotranspiration is estimated at the rate computed by the Thornthwaite equation.

d. Nitrogen concentrations in effluent from the preapplication treatment system are as follows:

Total Nitrogen as N	20 mg/L
Ammonia Nitrogen	15 mg/L

e. Nitrogen is applied to the site through rainfall and fixation at a rate of 5 lbs/acre-year.

f. Maximum loss to ammonia volatilization is 5% of the total ammonia applied. Maximum loss to denitrification for pine forest is 15% of the total nitrogen applied. Maximum loss to denitrification for Coastal Bermuda/Ryegrass is 10% of the total nitrogen applied.

g. Conservative net uptake of nitrogen in pine forest with understory growth is 200 lbs/acre-year. Table 5.6-1 shows a nitrogen content of 1.88% for Coastal Bermuda and 1.67% for Ryegrass. Anticipated yields for a double-cropped system are as follows:

   5 tons/acre of Bermuda during summer (April - September)

   1 ton/acre Bermuda, 1.5 tons/acre of Ryegrass during winter (October - March)

   This equates to an estimated crop nitrogen uptake of 188 lbs/acre during the summer and 88 lbs/acre during winter.

h. Delta P from Table 5.3-1 is assumed to be 2.5 inches.

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5.4.2 Design Percolation

As stated in Section 5.4.1, the average permeability of the most limiting soil layer is 0.213 inches/hour. As this limiting layer occurs at a depth less than 5 feet, 10 percent of this value will be used for design (reference Section 3.6.2). The design percolation rate becomes:

$$0.10 \times (0.213 \text{ in/hr}) \times (24 \text{ hr/day}) = 0.51 \text{ in/day}$$

5.4.3 Water Balance

Water balance calculations for the hypothetical 4-MGD land treatment system are presented in Table 5.4-1. This table makes use of eq. 3.7.2 to determine maximum allowable monthly hydraulic wastewater loadings.

Thornthwaite potential evapotranspiration and 5-year return monthly precipitation values for Atlanta are used in Table 5.4-1. The table indicates that for the assumed site conditions, the most critical water balance month is March, with a maximum allowable wastewater loading of 8.7 inches, corresponding to a rate of 2.0 inches/week. Therefore, a design wastewater loading rate greater than 2.0 inches/week will require water balance storage. Conversely, no water balance storage will be required for a design wastewater loading rate less than 2.0 inches/week (reference Section 3.9.3).

5.4.4 Nitrogen Balance

The nitrogen balance is used to evaluate wastewater loadings possible under different cover crop and management schemes. Tables 5.4-2, 5.4-3, and 5.4-4 present nitrogen balances for cover crop alternatives of pine forest and grass. Only an annual average is prepared for forested systems. Both summer and winter averages are prepared for grasses and other crops.

To meet a percolate nitrate limit of 7 mg/L, Table 5.4-2 indicates a pine forest cover crop will require a design wastewater loading rate less than 1.75 inches/week. Tables 5.4-3 and 5.4-4 indicate that a crop of Coastal Bermuda/Ryegrass will allow a design wastewater loading rate up to the maximum of 2.5 inches/week in summer and 1.75 inches/week in winter. The final cover crop selected is an economic decision balancing wetted area and storage requirements against operating cost.

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Table 5.4-1
WATER BALANCE CALCULATIONS

Month	Evap [a] (in/month)	Perc [b] (in/month)	Precip [c] (in/month)	Wastewater Loading Rates (in/month) [d]	(in/week) [e]
January	0.4	15.8	6.5	9.7	2.2
February	0.5	14.4	6.1	8.8	2.2
March	1.3	15.8	8.5	8.6	2.0 [f]
April	2.5	15.3	6.3	11.5	2.5 [g]
May	4.3	15.8	5.8	14.3	2.5
June	5.6	15.3	5.0	15.9	2.5
July	6.5	15.8	6.8	15.5	2.5
August	6.0	15.8	5.3	16.5	2.5
September	4.2	15.3	4.7	14.8	2.5
October	2.5	15.8	4.2	14.1	2.5
November	1.1	15.3	5.9	10.5	2.4
December	0.5	15.8	6.0	10.3	2.3
Total	35.2	186.4	71.1	150.5	

[a] Thornthwaite average monthly evapotranspiration. (P.E.T.)
[b] Number of days per month x 0.51 in/day (design percolation from Section 5.4.2)
[c] Five-year return, monthly precipitation
[d] Wastewater loading rate (in/month) = Evap + Perc – Precip.
[e] Wastewater loading rate (in/week) = WLR (in/month) / 4.42 (weeks/month). The maximum allowable is 2.5 in/week.
[f] 2.0 in/week (WLR_C) is the lowest value in column 6. In this example the month of March is the most critical water balance month.
[g] 11.5 in/month / 4.29 weeks/month = 2.7 in/week. Since 2.7 > maximum allowable, 2.5 in/week should be used, as (WLR_D).

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Table 5.4-2
NITROGEN BALANCE, PINE FOREST

1. Average Daily Flow ADF (MGD)	4.0 [a]	4.0	4.0	4.0
2. Average Design Wastewater Loading Rate (in/week)	1.25 [b]	1.5	**1.75** [o]	2.0
3. ADF Wetted Area (acre)	825 [c]	687	589	516
4. Nitrogen Input from Wastewater (lbs/acre-year)	295 [d]	355	414	472
5. Nitrogen Input from Rainfall and Fixation (lbs/acre-year)	5 [e]	5	5	5
6. Total Nitrogen Input (lbs/acre-year)	300 [f]	360	419	477
7. Ammonia Volatilization @ 5% of Ammonia applied (lbs/acre-year)	11 [g]	13	16	18
8. Denitrification @ 15% of Total Nitrogen applied (lbs/acre-year)	44 [h]	53	62	71
9. Net Plant Uptake and Storage (lbs/acre-year)	175 [i]	175	175	175
10. Nitrogen Leached by Percolate (lbs/acre-year)	70 [j]	118	166	214
11. Precipitation (in/year)	49 [k]	49	49	49
12. Wastewater Applied (in/year)	65 [l]	78	91	104
13. Potential Evapotranspiration P.E.T. (in/year)	35	35	35	35
14. Percolate (in/year)	79 [m]	92	105	118
15. Estimated Percolate Total Nitrogen (mg/L)	3.9 [n]	5.7	7.0	8.0

[a] Given value, 4 MGD
[b] Selected design loading(s)
[c] $\frac{\text{7 days/week x 4,000,000 gal/day x 12 in/ft}}{\text{7.48 gal/cu ft x 43,560 sq ft/acre x 1.25 in/week}}$
[d] Given Total Nitrogen value = 20 mg/L: $\frac{\text{20 mg/L x 4 MGD x 8.34 lb/gal x 365 day/year}}{\text{Line 3 value}}$
[e] Constant from atmosphere, 5 lbs/acre-year
[f] Line 4 value + Line 5 value
[g] Given Ammonia Nitrogen value = 15 mg/L: $\frac{\text{15 mg/L x 4 MGD x 8.34 lbs/gal x 365 day/year x 0.05}}{\text{Line 3 value}}$
[h] Line 6 value x 0.15
[i] Given, based on selected cover crop
[j] Line 6 value - Line 7 value - Line 8 value - Line 9 value
[k] Given, average precipitation value
[l] Line 2 value x 52 wks/year
[m] Line 11 value + Line 12 value - Line 13 value
[n] $\frac{\text{Line 10 value x 453,600 mg/lb}}{\text{Line 14 value x 102,750 L/acre-inch}}$
[o] Highest loading rate evaluated where percolate remains less than or equal to 7.0 mg/L

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Table 5.4-3
NITROGEN BALANCE, COASTAL BERMUDA/RYEGRASS, SUMMER

1. Average Daily Flow ADF (MGD)	4.0	4.0	4.0	4.0
2. Average Design Wastewater Loading Rate (in/week)	1.75	2.0	2.25	**2.5** [c]
3. ADF Wetted Area (acre)	589	516	458	412
4. Nitrogen Input from Wastewater (lbs/acre-period)	207 [a]	236	266	296
5. Nitrogen Input from Rainfall and Fixation (lbs/acre-period)	2.5	2.5	2.5	2.5
6. Total Nitrogen Input (lbs/acre-period)	210	239	269	299
7. Ammonia Volatilization @ 5% of Ammonia applied (lbs/acre-period)	8	9	10	11
8. Denitrification @ 10% of Total Nitrogen applied (lbs/acre-period)	21	24	27	30
9. Net Plant Uptake and Storage (lbs/acre-period)	188	188	188	188
10. Nitrogen Leached by Percolate (lbs/acre-period)	0 [b]	18	44	70
11. Precipitation (in/period)	24	24	24	24
12. Wastewater Applied (in/period)	46	52	59	65
13. Potential Evapotranspiration P.E.T. (in/period)	29	29	29	29
14. Percolate (in/period)	40	47	53	60
15. Estimated Percolate Total Nitrogen (mg/L)	0.0	1.7	3.6	5.1

[a] For this example, it is assumed that a constant amount of Nitrogen is applied to the field throughout the year. Actual design should take into account seasonal variations in N input.
Given Total Nitrogen value = 20 mg/L: $\frac{\text{20 mg/L x 4 MGD x 8.34 lb/gal x 182.5 day/period}}{\text{Line 3 value}}$

[b] Calculated amount of Nitrogen leached by percolate is negative.

[c] Highest loading rate evaluated where percolate remains less than or equal to 7.0 mg/L

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Table 5.4-4
NITROGEN BALANCE, COASTAL BERMUDA/RYEGRASS, WINTER

1. Average Daily Flow ADF (MGD)	4.0	4.0	4.0	4.0
2. Average Design Wastewater Loading Rate (in/week)	1. 5	**1.75** [a]	2.0	2.25
3. ADF Wetted Area (acre)	687	589	516	458
4. Nitrogen Input from Wastewater (lbs/acre-period)	177	207	236	266
5. Nitrogen Input from Rainfall and Fixation (lbs/acre-period)	2.5	2.5	2.5	2.5
6. Total Nitrogen Input (lbs/acre-period)	180	210	239	269
7. Ammonia Volatilization @ 5% of Ammonia applied (lbs/acre-period)	7	8	9	10
8. Denitrification @ 10% of Total Nitrogen applied (lbs/acre-period)	18	21	24	27
9. Net Plant Uptake and Storage (lbs/acre-period)	88	88	88	88
10. Nitrogen Leached by Percolate (lbs/acre-period)	68	93	118	144
11. Precipitation (in/period)	25	25	25	25
12. Wastewater Applied (in/period)	39	46	52	59
13. Potential Evapotranspiration P.E.T. (in/period)	6	6	6	6
14. Percolate (in/period)	58	65	71	78
15. Estimated Percolate Total Nitrogen (mg/L)	5.2	6.4	7.4	8.2

[a] Highest loading rate evaluated where percolate remains less than or equal to 7.0 mg/L

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5.4.5 Operating Scheme

The operating scheme for the hypothetical 4-MGD facility is as follows:

a. The average initial design wastewater loading rate during summer will be 2.5 inches/week. The actual loading rate will be somewhat less than 2.5 inches/week during normal operation because the additional acreage needed for treating the operational storage, water balance storage and wet weather/emergency storage will be used to treat the normal daily flows. This will be done in order to maintain the cover crop regardless of whether there is any water in storage.

b. The average initial design wastewater loading rate during winter will be less than or equal to 1.75 inches/week.

c. The maximum allowable instantaneous application rate is 0.213 in/hr (ref. 5.4.1-b). For this example an instantaneous application rate of 0.20 in/hr will be used.

d. The cover crop will be Coastal Bermuda overseeded in the winter with Ryegrass. The crop will be harvested and sold.

e. Normal operation will be five (5) days per week. The flow from the other two days will be stored. Since the system will normally be operated five days per week, the wastewater volume applied each day is:

$$[(7 \text{ days/week})/(5 \text{ days/week})] \times 4 \text{ MGD} = 5.6 \text{ MGD}$$

5.4.6 Storage Volume Requirements

As discussed in Section 3.9, the required storage volume consists of three (3) <u>separate</u> storage components.

a. Operational Storage

The operating scheme selected for design calls for irrigation five days per week with storage of two days' flow. The required operational storage is:

$$(7 \text{ days} - 5 \text{ days}) \times 4 \text{ MGD} = 8 \text{ MG}$$

For this example it is assumed that harvesting of the grass will not occur during the wet weather months. Therefore, no additional storage will be needed for fields out of service due to harvesting since the wet weather storage volume will be available.

b. Wet Weather and Emergency Storage

Minimum requirements for wet weather and emergency storage are discussed in Section 3.9.2. These are the greater of 12 days flow or the results of eq. 3.9.2 .

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For the hypothetical facility, Delta P from Table 5.3-1 is 2.5 inches. The maximum allowable hydraulic wastewater loading rate in the most critical water balance month (March) from Table 5.4-1 is 8.6 inches/month. By eq. 3.9.2:

$$\frac{2.5 \text{ inch x } 365 \text{ days/year}}{12 \text{ month/year x } 8.6 \text{ in/month}} = 8.8 \text{ days}$$

8.8 days is less than the 12-day minimum storage requirement. Therefore, the required wet weather and emergency storage is:

12 days x 4 MGD = 48 MG

c. Water Balance Storage

As discussed in section 3.9.3, the water balance storage is a function of hydraulic loading rate, which is a function of the total wetted field area. Therefore, before the water balance storage can be determined the wetted field area must be defined.

5.4.7 Wetted Field Area Determination

The area required for the irrigation site is the total of four separate components, as discussed in Section 3.10.

A(wetted) = A(ADF) + A(OP) + A(WW/E) + A(WBS)

Substituting the appropriate loading rates and the appropriate volumes into equations 3.10.1 and 3.10.3 results in the following wetted area requirements:

$$A(ADF) = \frac{7 \text{ days/wk operation x } 4{,}000{,}000 \text{ gpd x } 12 \text{ in/ft}}{7.48 \text{ gal/cf x } 43{,}560 \text{ sf/acre x } 1.75^{a} \text{ in/wk}}$$

a This site is nitrogen-limited in the winter at 1.75 in/week (see nitrogen balance). If the site were hydraulically limited, the design wastewater loading rate, (WLR_D) would be used.

A(ADF) = 589 acres

$$A(WW/E) = \frac{12 \text{ days storage x } 4{,}000{,}000 \text{ gpd x } 7 \text{ days/wk x } 12 \text{ in/ft}}{7.48 \text{ gal/cf x } 43{,}560 \text{ sf/acre x } 90 \text{ days x } 1.75^{b} \text{ in/wk}}$$

b 1.75 in/wk is the most critical wastewater loading rate, WLR_C, since the site is nitrogen-limited in winter at 1.75 in/wk (see nitrogen balance).

A(WW/E) = 79 acres

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$$A(OP) = \frac{\text{2 days storage x 4,000,000 gpd x 7 days/wk x 12 in/ft}}{\text{7.48 gal/cf x 43,560 sf/acre x 90 days x 1.75}^{\,b}\text{ in/wk}}$$

A(OP) = 13 acres

With these areas determined the next step is to define the necessary water balance storage and the wetted field area associated with that storage. The actual wastewater loading rate (WLR_A) is:

$$WLR_A = \frac{\text{7 days/wk x 4,000,000 gpd x 12 in/ft}}{\text{7.48 gal/cf x 43,560 sf/acre x 681}^{\,c}\text{ acres}}$$

c A(ADF) 589 acres + A(WW/E) 79 acres + A(OP) 13 acres = 681 acres

WLR_A = 1.51 in/wk

Table 5.4-5 combines eq. 3.7.2 and 3.9.3 to determine the required water balance storage volume, V(WBS), for a loading rate of 1.51 in/wk. The table indicates a water balance storage requirement of 0.0 inches over the wetted area. Storage for the most critical month (March) is:

$$V(WBS) = \frac{\text{0.0 in. x 681 acres x 7.48 gal/cf x 43,560 sf/acre}}{\text{12 inches}} = \text{0 MG}$$

Substituting the appropriate values into eq. 3.10.4:

$$A(WBS) = \frac{\text{0 gal x 7 days/wk x 12 in/ft}}{\text{90 days x 7.48 gal/cf x 43,560 sf/acre x 1.51 in/wk}}$$

A(WBS) = 0 acres

The total area necessary for this land treatment system is:

A(ADF) + A(OP) + A(WW/E) + A(WBS) = A(TOTAL)

589 acres + 13 acres + 79 acres + 0 acres = 681 acres

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Table 5.4-5
WATER BALANCE STORAGE

Month	WLR_A [a] (in/month)	WLR_D [b] (in/month)	WBS [c] (in/month)	Sum WBS [d] (in/month)
January	6.7 [e]	9.7 [f]	0.0	0.0
February	6.1	8.8	0.0	0.0
March	6.7	8.6	0.0	0.0
April	6.5	11.5	0.0	0.0
May	6.7	14.3	0.0	0.0
June	6.5	15.9	0.0	0.0
July	6.7	15.5	0.0	0.0
August	6.7	16.5	0.0	0.0
September	6.5	14.8	0.0	0.0
October	6.7	14.1	0.0	0.0
November	6.5	10.5	0.0	0.0
December	6.7	10.3	0.0	0.0

[a] Based on the number of days per month and the actual wastewater loading of 1.51 in/week, assumes all influent wastewater is applied to irrigation fields.
[b] Values from Table 5.4-1
[c] WBS = Water balance storage, reference eq. 3.9.3. A negative WBS value indicates that no WBS is required for that month. A positive WBS value indicates that WBS is required for that month.
[d] Cumulative sum of WBS values
[e] $\frac{31 \text{ days/month}}{7 \text{ days/week}} \times 1.51$ in/wk = 6.7 inches/month
[f] 6.7 - 9.7 = -3, the value is negative which indicates that no WBS is required for this month

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5.5 Drip System Example Calculations

5.5.1 Introduction and Assumptions

Design of slow-rate land treatment systems is a process of balancing site limitations against construction and operating costs. The following example calculations are for a hypothetical 0.5 MGD facility in the coastal area of Georgia. They illustrate the basic computations required and the relationship between variables.

The following assumptions were made. They must not be used for real world systems without verification.

a. The average design flow is 0.5 MGD with a daily peak factor of 2 and a weekly peak factor of 1.25.

b. The land treatment site is moderately well drained with seasonal high groundwater more than 5 feet below the surface. The most limiting layer in the soil profile occurs at a depth of 2 to 4 feet. Testing for saturated vertical hydraulic conductivity indicates an average permeability for this layer of 0.000106 cm/s corresponding to 0.150 inches/hour.

c. The annual average precipitation is 89 inches. Evapotranspiration is estimated at the rate computed by the Thornthwaite equation.

d. Nitrogen concentrations in effluent from the preapplication treatment system are as follows:

Total Nitrogen as N	20 mg/L
Ammonia Nitrogen	15 mg/L

e. Nitrogen is applied to the site through rainfall and fixation at a rate of 5 lbs/acre-year.

f. Maximum loss to ammonia volatilization is 0% of the total ammonia applied. Maximum loss to denitrification for pine forest is 25% of the total nitrogen applied. Maximum loss to denitrification for Coastal Bermuda/Ryegrass is 15% of the total nitrogen applied.

g. Conservative net uptake of nitrogen in pine forest with understory growth is 200 lbs/acre-year. Nitrogen uptake and removal for Coastal Bermuda grass is 300 lbs/acre-year. It has been assumed that there is a crop nitrogen uptake for Coastal Bermuda of 200 lbs/acre during summer and 100 lbs/acre during winter.

i. Delta P is assumed to be 2.5 inches.

5.5.2 Design Percolation

As stated in Section 5.5.1, the average permeability of the most limiting soil layer is 0.150 inches/hour. As this limiting layer occurs at a depth less than 5 feet, 10 percent of this value will be used for design (reference Section 3.6.2). The design percolation rate becomes:

$$0.10 \text{ x } (0.150 \text{ in/hr}) \text{ x } (24 \text{ hr/day}) = 0.36 \text{ in/day}$$

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5.5.3 Water Balance

Water balance calculations for the hypothetical 0.5-MGD land treatment system are presented in Table 5.5-1. This table makes use of eq. 3.7.2 to determine maximum allowable monthly hydraulic wastewater loadings.

Thornthwaite potential evapotranspiration and 5-year return monthly precipitation values for Coastal Georgia are used in Table 5.5-1. The table indicates that for the assumed site conditions, the most critical water balance month is December, with a maximum allowable wastewater loading of 3.7 inches, corresponding to a rate of 0.84 inches/week. Therefore, a design wastewater loading rate greater than 0.84 inches/week will require water balance storage. Conversely, no water balance storage will be required for a design wastewater loading rate less than 0.84 inches/week (reference Sections 3.7 & 3.10).

5.5.4 Nitrogen Balance

The nitrogen balance is used to evaluate wastewater loadings possible under different cover crop and management schemes. Tables 5.5-2, 5.5-3, and 5.5-4 present nitrogen balances for cover crop alternatives of pine forest and grass. Only an annual average is prepared for forested systems. Both summer and winter averages are prepared for grasses and other crops.

To meet a percolate nitrate limit of 7 mg/L, Table 5.5-2 indicates a pine forest cover crop will require a design wastewater loading rate less than 2.8 inches/week. Table 5.5-3 and 5.5-4 indicates that a crop of Coastal Bermuda/Ryegrass will allow a design wastewater loading rate up to 1.6 inches/week. The final cover crop selected is an economic decision balancing wetted area and storage requirements against operating cost.

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Table 5.5-1
WATER BALANCE CALCULATIONS

Month	Evap [a] (in/month)	Perc [b] (in/month)	Precip [c] (in/month)	Wastewater Loading Rates (in/month) [d]	(in/week) [e]
January	0.9	11.2[f]	7.2	4.9	1.1
February	0.5	10.1[i]	6.5	4.1[g]	1.0[h]
March	0.4	11.2	7.3	4.3	0.97
April	0.5	10.8	9.2	5.8	1.4
May	1.1	11.2	7.4	4.9	1.1
June	1.9	10.8	8.7	4.0	0.93
July	2.8	11.2	8.0	6.0	1.4
August	3.4	11.2	9.6	5.0	1.2
September	3.8	10.8	5.3	9.3	2.2
October	3.5	11.2	4.4	10.3	2.3[h]
November	2.7	10.8	6.0	7.5	1.8
December	1.7	11.2	9.2	3.7	0.84[i]
Total	23.20	131.7	88.80	69.8	

[a] Thornthwaite average monthly evapotranspiration. (P.E.T.)
[b] Number of days per month x 0.36 in/day (design percolation from Section 5.5.2)
[c] Five-year return, monthly precipitation
[d] Wastewater loading rate (in/month) = Evap + Perc – Precip.
[e] Wastewater loading rate (in/week) = WLR (in/month) / 4.42 (weeks/month). The maximum allowable is 2.8 in/week.
[f] The maximum allowable hydraulic wastewater loading rate is 11.2 in/month. This (11.2 in/month) is the maximum value that can be used. No values in column 5 may exceed this value.
[g] 0.5 + 10.1 – 6.5 = 4.1 in/month.
[h] 4.1 in/month / 4.28 weeks per month = 1.0 in/wk.
[i] 0.84 in/wk is the lowest value in column 6. In this example the month of December is the most critical water balance month.

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Table 5.5-2
NITROGEN BALANCE, PINE FOREST

1. Average Daily Flow ADF (MGD)	0.5 [a]	0.5	0.5	0.5
2. Average Design Wastewater Loading Rate (in/week)	0.8 [b]	1.2	1.6	**2.0** [p]
3. ADF Wetted Area (acre)	161.1 [c]	107.4	80.6	64.5
4. Nitrogen Input from Wastewater (lbs/acre-year)	189 [d]	283	378	472
5. Nitrogen Input from Rainfall and Fixation (lbs/acre-year)	5 [e]	5	5	5
6. Total Nitrogen Input (lbs/acre-year)	194 [f]	288	383	477
7. Ammonia Volatilization @ 5% of Ammonia applied (lbs/acre-year)	0 [g]	0	0	0
8. Denitrification @ 15% of Total Nitrogen applied (lbs/acre-year)	29 [h]	43	58	72
9. Net Plant Uptake and Storage (lbs/acre-year)	200 [i]	200	200	200
10. Nitrogen Leached by Percolate (lbs/acre-year)	0 [j]	45	125	205
11. Precipitation (in/year)	88.8 [k]	88.8	88.8	88.8
12. Wastewater Applied (in/year)	42 [l]	62	83	104
13. Potential Evapotranspiration P.E.T. (in/year)	23 [m]	23	23	23
14. Percolate (in/year)	108 [n]	128	149	170
15. Estimated Percolate Total Nitrogen (mg/L)	0.0 [o]	1.55	3.70	5.30

[a] Given value, 0.5 MGD

[b] Selected design loading(s). Water Balance indicates maximum of 0.84 in/wk. Selected loading(s) that exceed 0.84 in/wk will require water balance storage.

[c] 7 days/week x 500,000 gal/day x 12 in/ft
7.48 gal/cu ft x 43,560 sq ft/acre x 0.8 in/week

[d] Given Total Nitrogen value = 20 mg/L: 20 mg/L x 0.5 MGD x 8.34 lb/gal x 365 day/year
Line 3 value

[e] Constant from atmosphere, 5 lbs/acre-year

[f] Line 4 value + Line 5 value

[g] Assumed as 0 for subsurface systems

[h] Line 6 value x 0.15

[i] Given, based on selected cover crop

[j] Line 6 value - Line 7 value - Line 8 value - Line 9 value

[k] Given, average precipitation value

[l] Line 2 value x 52 wks/year

[m] From Table 5.5.1

[n] Line 11 value + Line 12 value - Line 13 value

[o] Line 10 value x 4.41
Line 14 value

[p] Highest loading rate evaluated where percolate remains less than or equal to 7.0 mg/L

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Table 5.5-3
NITROGEN BALANCE, COASTAL BERMUDA/RYEGRASS, SUMMER

1. Average Daily Flow ADF (MGD)	0.5	0.5	0.5	0.5
2. Average Design Wastewater Loading Rate (in/week)	0.8	1.2 [a]	1.6	**2.0** [c]
3. ADF Wetted Area (acre)	161.1	107.4	80.6	64.5
4. Nitrogen Input from Wastewater (lbs/acre-period)	95	142	189	236
5. Nitrogen Input from Rainfall and Fixation (lbs/acre-period)	5	5	5	5
6. Total Nitrogen Input (lbs/acre-period)	100	147	194	241
7. Ammonia Volatilization @ 5% of Ammonia applied (lbs/acre-period)	0	0[b]	0	0
8. Denitrification @ 10% of Total Nitrogen applied (lbs/acre-period)	10	15	19	24
9. Net Plant Uptake and Storage (lbs/acre-period)	200	200	200	200
10. Nitrogen Leached by Percolate (lbs/acre-period)	0	0	0	17
11. Precipitation (in/period)	50	50	50	50
12. Wastewater Applied (in/period)	21	31	42	52
13. Potential Evapotranspiration P.E.T. (in/period)	23	23	23	23
14. Percolate (in/period)	48	58	69	79
15. Estimated Percolate Total Nitrogen (mg/L)	0.0	0.0	0.0	0.95

[a] This loading exceeds the maximum loading of 0.84 in/week without water balance storage. Additional acreage will be required to eliminate the stored volume for this and all subsequent flows greater than 0.84 in/week.

[b] No ammonia volatilization is anticipated with subsurface distribution.

[c] Highest loading rate evaluated where percolate remains less than or equal to 7.0 mg/L

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Table 5.5-4
NITROGEN BALANCE, COASTAL BERMUDA/RYEGRASS, WINTER

1. Average Daily Flow ADF (MGD)	0.5	0.5	0.5	0.5
2. Average Design Wastewater Loading Rate (in/week)	0.8	1.2 [a]	**1.6** [c]	2.0
3. ADF Wetted Area (acre)	161.1	107.4	80.6	64.5
4. Nitrogen Input from Wastewater (lbs/acre-period)	95	142	189	236
5. Nitrogen Input from Rainfall and Fixation (lbs/acre-period)	5	5	5	5
6. Total Nitrogen Input (lbs/acre-period)	100	147	194	241
7. Ammonia Volatilization @ 5% of Ammonia applied (lbs/acre-period)	0	0[b]	0	0
8. Denitrification @ 10% of Total Nitrogen applied (lbs/acre-period)	10	15	19	24
9. Net Plant Uptake and Storage (lbs/acre-period)	100	100	100	100
10. Nitrogen Leached by Percolate (lbs/acre-period)	0	32	75	117
11. Precipitation (in/period)	38	38	38	38
12. Wastewater Applied (in/period)	21	31	42	52
13. Potential Evapotranspiration P.E.T. (in/period)	23	23	23	23
14. Percolate (in/period)	36	46	57	67
15. Estimated Percolate Total Nitrogen (mg/L)	0.0	3.1	5.8	7.7

[a] This loading exceeds the maximum loading of 0.84 in/week without water balance storage. Additional acreage will be required to eliminate the stored volume for this and all flows greater than 0.84 in/week.

[b] No ammonia volatilization is anticipated with subsurface distribution.

[c] Highest loading rate evaluated where percolate remains less than or equal to 7.0 mg/L

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5.5.5 Operating Scheme

The operating scheme for the hypothetical 0.5-MGD facility is as follows:

a. The selected cover crop will be Coastal Bermuda. The crop will be harvested and sold.

b. Based on the nitrogen balance calculations for winter, the average initial design wastewater loading rate will be 1.60 inches/week. The actual loading rate will be somewhat less than 1.60 inches/week during normal operation because the additional acreage needed for treating the operational storage, water balance storage and wet weather/emergency storage will be used to treat the normal daily flows. This will be done in order to maintain the cover crop regardless of whether there is any water in storage.

c. The maximum allowable instantaneous application rate is 0.150 in/hr (ref. 5.5.1-b). For this example an instantaneous application rate of 0.30 in/hr will be used. This equates to drippers producing 0.75 gal/hr on 2 ft. centers with lines spaced at 2 ft. intervals. (Note that the application rate exceeds permeability. This is only possible with subsurface applications and short periods of operation. If application rates exceed one hour, the soil permeability is the maximum instantaneous application rate allowed.)

d. The soil permeability is 0.15 in/hr. The particle density is 1.5 g/cm^3. A check of the potential soil storage capacity (eq 3.9.) is needed to determine if the minimum dripper line depth of 8 inches is adequate. Assuming that 35% of the voids are available and that the soil is at 70% saturation, the burial depth is:

   $$D = 0.75 / 7.48 / [0.35 \times (1-1.5/2.65) \times (1-0.7)] / (2 \times 2) \times 12 = 6.6\text{in/hr (adequate)}$$

e. Normal operation will be five (5) days per week. The flow from the other two days will be stored. Since the system will normally be operated five days per week, the wastewater volume applied each day is:

   $$[(7 \text{ days/week})/(5 \text{ days/week})] \times 0.5 \text{ MGD} = 0.7 \text{ MGD}$$

5.5.6 Storage Volume Requirements

As discussed in Section 3.9, the required storage volume consists of three (3) <u>separate</u> storage components.

a. Operational Storage

   The operating scheme selected for design calls for irrigation five days per week with storage of two days' flow. The required operational storage is:

   $$(7 \text{ days} - 5 \text{ days}) \times 0.5 \text{ MGD} = 1.0 \text{ MG}$$

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For this example it is assumed that harvesting of the grass will not occur during the wet weather months. Therefore, no additional storage will be needed for fields out of service due to harvesting since the wet weather storage volume will be available.

b. Wet Weather and Emergency Storage

Minimum requirements for wet weather and emergency storage are discussed in Section 3.10.2. These are the greater of 3 days flow or the results of eq. 3.9.2.

For the hypothetical facility, Delta P from Table 5.3-1 is 2.5 inches. The maximum allowable hydraulic wastewater loading rate in the most critical water balance month (December) from Table 5.4-1 is 3.7 inches/month. By eq. 3.10.2:

$$\frac{2.5 \text{ inch x } 365 \text{ days/year}}{12 \text{ month/year x } 3.7 \text{ in/month}} = 20.6 \text{ days}$$

20.6 days is greater than the 3-day minimum storage requirement. Therefore, the required wet weather and emergency storage is:

20.6 days x 0.5 MGD = 10.3 MG

Note that for an actual subsurface installation wet weather storage is not required. Emergency storage is always required.

c. Water Balance Storage

As discussed in section 3.10.3, the water balance storage is a function of hydraulic loading rate, which is a function of the total wetted field area. Therefore, before the water balance storage can be determined the wetted field area must be defined.

5.5.7 Wetted Field Area Determination

The area required for the irrigation site is the total of four separate components, as discussed in Section 3.12.

A(wetted) = A(ADF) + A(OP) + A(WW/E) + A(WBS)

Substituting the appropriate loading rates and the appropriate volumes into equations 3.12.1 and 3.12.3 results in the following wetted area requirements:

$$A(ADF) = \frac{7 \text{ days/wk operation x } 500{,}000 \text{ gpd x } 12 \text{ in/ft}}{7.48 \text{ gal/cf x } 43{,}560 \text{ sf/acre x } 1.60^{a} \text{ in/wk}}$$

[a] 1.60 in/wk is the maximum allowable wastewater loading rate as selected.

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A(ADF) = 80.6 acres

$$A(WW/E) = \frac{20.6 \text{ days storage} \times 500{,}000 \text{ gpd} \times 7 \text{ days/wk} \times 12 \text{ in/ft}}{7.48 \text{ gal/cf} \times 43{,}560 \text{ sf/acre} \times 90 \text{ days} \times 0.84^{b} \text{ in/wk}}$$

[b] 0.84 in/wk is the most critical water balance month wastewater loading.

A(WW/E) = 35.1 acres

Since the only operational storage is associated with applying less than 7 days per week:

$$A(OP) = \frac{2 \text{ days storage} \times 500{,}000 \text{ gpd} \times 7 \text{ days/wk} \times 12 \text{ in/ft}}{7.48 \text{ gal/cf} \times 43{,}560 \text{ sf/acre} \times 90 \text{ days} \times 1.6^{b} \text{ in/wk}}$$

A(OP) = 1.8 acres

With these areas determined the next step is to define the necessary water balance storage and the wetted field area associated with that storage. The actual wastewater loading rate (WLR_A) is:

$$WLR_A = \frac{7 \text{ days/wk} \times 500{,}000 \text{ gpd} \times 12 \text{ in/ft}}{7.48 \text{ gal/cf} \times 43{,}560 \text{ sf/acre} \times 117.5^{c} \text{ acres}}$$

[c] A(ADF) 80.6 acres + A(WW/E) 35.1 acres + A(OP) 1.8 acres = 117.5 acres

WLR_A = 1.09 in/wk

Table 5.5-5 combines eq. 3.7.2 and 3.9.3 to determine the required water balance storage volume, V(WBS), for a loading rate of 1.09 in/wk. The table indicates a water balance storage requirement of 1.13 inches over the wetted area of 117.5 acres. Storage for the most critical month (December) is:

$$V(WBS) = \frac{1.13 \text{ in.} \times 117.5 \text{ acres} \times 7.48 \text{ gal/cf} \times 43{,}560 \text{ sf/acre}}{12 \text{ inches}} = 3.605 \text{ MG}$$

Substituting the appropriate values into eq. 3.11.4:

$$A(WBS) = \frac{3{,}605{,}000 \text{ gal} \times 7 \text{ days/wk} \times 12 \text{ in/ft}}{90 \text{ days} \times 7.48 \text{ gal/cf} \times 43{,}560 \text{ sf/acre} \times 1.09 \text{ in/wk}}$$

A(WBS) = 9.5 acres

The total area necessary for this land treatment system is:

A(ADF) + A(OP) + A(WW/E) + A(WBS) = A(TOTAL)

80.6 acres + 1.8 acres + 35.1 acres + 9.5 acres = 127 acres

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Applying 0.7 MG [0.5 MG + ((0.5 MG x 2 days)/5days)] each day for five days per week, the wetted field area will be divided into five 25.4 acre sections. For normal flows each field will be loaded at a rate of:

$$\frac{0.7 \times 10^6 \text{ gal} \times 12 \text{ in/ft}}{7.48 \text{ gal/cf} \times 43{,}560 \text{ sf/acre} \times 25.4 \text{ acres}} = 1.01 \text{ in/wk}$$

*The average wastewater irrigation period will be:

(1.01 in/wk)/[(1 day/week) x (0.30 in/hr)] = 3.4 hr/day.

*The maximum wastewater irrigation period will be:

(1.6 in/week)/[(1 day/week) x (0.30 in/hr)] = 5.3 hr/day.

*Note that the 0.30 in/hr exceeds the actual permeability of the soil. This example assumes 24 hour per day operation with the irrigation periods broken down throughout the 24 hour period. Actual system operation must be adjusted to the variable seasonal conditions when maximum application rates (instantaneous or maximum) are used.

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Table 5.5-5
WATER BALANCE STORAGE

Month	WLR_A [a] (in/month)	WLR_D [b] (in/month)	WBS [c] (in/month)	Sum WBS [d] (in/month)
January	4.83 [e]	4.9	0.0	0.0
February	4.36	4.1	0.26	0.26
March	4.83	4.3	0.53	0.79
April	4.67	5.8	0.0	0.0
May	4.83	4.9	0.0	0.0
June	4.67	4.0	0.67	0.67
July	4.83	6.0	0.0	0.0
August	4.83	5.0	0.0	0.0
September	4.67	9.3	0.0	0.0
October	4.83	10.3	0.0	0.0
November	4.67	7.5	0.0	0.0
December	4.83	3.7	1.13	1.13

[a] Based on the number of days per month and the actual wastewater loading of 1.09 in/week, assumes all influent wastewater is applied to irrigation fields.
[b] Values from Table 5.5-1
[c] WBS = Water balance storage, reference eq. 3.9.3. A negative WBS value indicates that no WBS is required for that month. A positive WBS value indicates that WBS is required for that month.
[d] Cumulative sum of WBS values
[e] 31 days/month = 4.42 weeks/month
4.42 wk/month x 1.09 in/wk = 4.9 inches/month

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5.6 Recommended Design Guidance

Colorado School of Mines Guidance for Evaluation of Potential Groundwater Mounding Associated with Cluster and High-Density Wastewater Soil Absorption Systems (Poeter et. al., 2005).

Process Design Manual, Land Treatment of Municipal Wastewater Effluents (U.S. EPA, 2006).

Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins (U. S. Department of the Interior, 2010).

Growth and decay of groundwater-mounds in response to uniform percolation (Hantush, M.S., 1967).

Hantush 1967 Groundwater Mounding Equation Worksheet - United States Geological Survey https://pubs.usgs.gov/sir/2010/5102/

Modflow 6: USGS Modular Hydrologic Model – United States Geological Survey

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5.6.1 Reference Tables

Table 5.6-1
YIELD BASED NITROGEN, PHOSPHORUS, & POTASSIUM UPTAKE OF VARIOUS CROPS

UNITED STATES EPA 2006, PROCESS DESIGN MANUAL
LAND TREATMENT OF MUNICIPAL WASTEWATER EFFLUENTS

Percent of Dry Harvested Material

Forage Crops	Dry Weight	Typ. Yield/acre-yr	N	P	K
Barley	48 lb/bushel	50 bushel	1.82	0.34	0.43
		1 ton straw	0.75	0.11	1.25
Corn	56 lb/bushel	120 bushel	1.61	0.28	0.40
		4.5 ton straw	1.11	0.20	1.34
Cotton		600 lbs Lint	2.67	0.85	0.83
		1000 lbs stalks	1.75	0.22	1.45
Grain Sorghum	56 lb/bushel	60 bushel	1.67	0.36	0.42
		3 tons straw	1.08	0.15	1.31
Soybeans [a]	60 lb/bushel	35 bushel	6.25	0.64	1.90
		2 tons stover	2.25	0.22	1.04
Wheat	60 lb/bushel	40 bushel	2.08	0.62	0.52
		1.5 tons straw	0.67	0.07	0.97

Field Crops	Typ. Yield/acre-yr	N	P	K
Alfalfa [a]	4 tons	2.25	0.22	1.87
Bahiagrass	3 tons	1.27	0.13	1.73
Bromegrass	5 tons	1.87	0.21	2.55
Clover-grass	6 tons	1.52	0.27	1.69
Coastal Bermuda Grass	8 tons	1.88	0.19	1.40
Kentucky Blue Grass	2 tons	2.91	0.43	1.95
Orchardgrass	6 tons	1.47	0.20	2.16
Reed Canary Grass	6.5 tons	1.35	0.18	1.66
Ryegrass	5 tons	1.67	0.27	1.42
Switchgrass	3 tons	1.15	0.10	1.90
Tall Fescue	3.5 tons	1.97	0.20	2.00

[a] Legumes will also take nitrogen from the atmosphere.

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Table 5.6-2
ESTIMATED NITROGEN UPTAKE FOR SELECTED FOREST ECOSYSTEMS WITH WHOLE TREE HARVESTING

UNITED STATES EPA 2006 PROCESS DESIGN MANUAL
LAND TREATMENT OF MUNICIPAL WASTEWATER EFFLUENTS

	Tree Age (years)	Average Annual Nitrogen Uptake (lb/acre/year)
Eastern Forest		
Mixed Hardwoods	40 - 60	200
Red Pine	25	100
Old Field w/ White Spruce Plantation	15	200
Pioneer Succession	5 - 15	200
Aspen Sprouts	-	100
Southern Forests		
Mixed Hardwoods	40 - 60	250
Loblolly Pine with no Understory	20	200
Loblolly Pine with Understory	20	250
Lake States Forests		
Mixed Hardwoods	50	100
Hybrid Poplar [a]	5	140
Western Forests		
Hybrid Poplar [a]	4 - 5	270
Douglas Fir Plantation	15 - 25	200

[a] Short-term rotation with harvesting at 4 - 5 years; represents first growth cycle from planted seedlings.

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Table 5.6-3
SUGGESTED VALUES FOR INORGANIC CONSTITUENTS IN WASTEWATER APPLIED TO LAND
Based on (Georgia DNR, 1978; U.S. EPA, 1976 & 1981)

Potential Problem and Constituent	No Problem	Increasing Problem	Severe
pH (standard units)	6.5 - 8.4	4.2 - 6.5	< 4.2 or > 8.4
Permeability			
Electrical Conductivity (µmho/cm)	> 0.50		< 0.2
Sodium Adsorption Ratio [a]	2.0		>5.0
Salinity			
Electrical Conductivity (µmho/cm)	< 0.75	0.75 - 3.0	> 3.0
Specific Ions – Anions			
Bicarbonate as $CaCO_3$, (meq/L)	< 1.5	1.5 - 8.5	> 8.5
(mg/L)	< 90	90 - 520	> 520
Chloride (mg/L)	< 142	142 - 355	> 355
Specific Ions – Cations			
Ammonia (mg/L as N)	< 5.0	5.0 - 30	> 30
Sodium (meq/L)	< 3.0	> 3.0	
(mg/L)	< 69	> 69	
Specific Ions - Trace Metals			
Arsenic (mg/L)	< 0.1	0.1 - 0.2	0.2 - >2.0
Beryllium (mg/L)	< 0.1	0.1 - 0.2	0.2 - >0.5
Boron (mg/L)	< 0.5	0.5 - 1.4	1.4 - >2.0
Cadmium (mg/L)	< 0.01	0.01 - 0.02	0.02 - >0.05
Chromium (mg/L)	< 0.1	0.1 - 0.2	0.2 - >1.0
Cobalt (mg/L)	< 0.1	0.1 - 0.5	0.5 - >5
Copper (mg/L)	< 0.2	0.2 - 0.4	0.4 - >5
Iron (mg/L)	< 10	5 - 10	10 - >20

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Potential Problem and Constituent	No Problem	Increasing Problem	Severe
Lead (mg/L)	< 10	5 - 10	10 - >20
Lithium (mg/L)	< 2.0	2.0 - 2.5	> 2.5
Mercury (mg/L)	no standard		
Molybdenum (mg/L)	< 0.01	0.01 - 0.02	0.02 - >0.05
Nickel (mg/L)	< 0.2	0.2 - 0.4	0.4 - >2.0
Selenium (mg/L)	< 0.02	0.02 - 0.04	> 0.04
Zinc (mg/L)	< 2.0	2.0 - 4.0	4 -> 10

[a] Sodium Adsorption Ratio = $\frac{Na^{+1}}{\text{SQRT}\ [(Ca^{+2} + Mg^{+2})/\ 2]}$

Where Na^{+1}, Ca^{+2} and Mg^{+2} in the wastewater are expressed in milliequivalents per liter (meq/L) and SQRT represents "square root of".

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Table 5.6-4
HYDRAULIC CONDUCTIVITY TEST METHODS

1.0 Saturated Vertical Hydraulic Conductivity [a]

1.1 Laboratory Tests: [b]

Constant Head Method (coarse-grained soils)	ASTM D 2434-68 AASTHO T 215-70 Bowles (1978), pp 97-104 Kezdi (1980), pp 96-102
Falling Head Method [c] (cohesive soils)	Bowles (1978), pp 105-110 Kezdi (1980), pp 102-108

1.2 Field Tests:

Ring Permeameter Method	Boersma (1965) U.S. EPA (1981), pp 3-22 to 23
Double Tube Method	Bouwer and Rice (1966) U.S. EPA (1981), pp 3-22 to 24
Air-Entry Permeameter Method	Bouwer (1966) Reed and Crites (1984), pp 176 to 180 Topp and Binns (1976) U.S. EPA (1981), pp 3-22 to 27
Constant Head Permeameter [c]	Amoozegar (1989) Soil Sci. Soc. Am. J. 53:1356-1361

2.0 Saturated Horizontal Hydraulic Conductivity [a, d]

2.1 Field Tests:

Auger Hole Method	Reed and Crites (1984), pp 165 to 168 U.S. EPA (1984), pp 3-31 to 35
Slug or Pump Testing [c]	Bouwer and Rice (1976) Freeze and Cherry (1979)

[a] Other methods, properly documented, may be accepted by EPD. However, "standard" percolation tests as performed for septic tank drain fields are not acceptable.

[b] These tests require <u>undisturbed</u> field samples properly prepared to ensure saturation. Reconstructed field samples are not acceptable. A description of the field sampling technique should accompany the laboratory testing results.

[c] Methods recommended by EPD.

[d] Testing for saturated horizontal hydraulic conductivity is required at land treatment sites where lateral, as opposed to vertical subsurface drainage, is the predominant drainage pathway. Testing for saturated horizontal hydraulic conductivity and other aquifer characteristics also may be necessary as part of a groundwater mounding analysis.

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