DWR-NPDES-SOP-14- WW Design Criteria Chapter 9-03012022
Design Criteria for Review of Sewage Works Construction Plans and Documents
Chapter 9

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Revision History Table

Revision	Date	Brief Summary of Change
0	07/28/2014	Initial issue
1	03/12/2022	Overall update to Chapter 9

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CHAPTER 9
Impoundment, Ponds, and Aerated Lagoons

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9.1 General

The criteria contained in this chapter are applicable to all new, expanded, and/or modified ponds, impoundments, and lagoons that contain wastes or wastewater associated with activities under operational permits issued by the Division of Water Resources. These wastes and wastewaters include, but are not necessarily limited to:

- Municipal Sewage
- Industrial wastewater and Non-hazardous Industrial sludge
- Food Processing wastewater and solids
- Concentrated Animal Feeding Operation (CAFO) wastewater and solids
- Stormwater
- Municipal waste activated sludge (WAS), water treatment plant sludge, wastewater treatment plant sludge, and biosolids

These criteria apply to units independent of whether the unit is part of the treatment process (includes equalization) or is used for storage.

This chapter describes the requirements for impoundments, including the following biological treatment processes:

a. Stabilization ponds
b. Aerated lagoons

Additionally, this chapter describes the requirements for use of hydraulic control release lagoons for effluent disposal.

In the case of impoundments/ponds related to coal combustion residuals (CCRs), the applicable federal requirements will not be or are not superseded by these guidelines.

9.1.1 Applicability

In general, impoundments, ponds, and aerated lagoons are most applicable to small and/or rural communities where land is available at a low cost and minimum secondary treatment requirements are acceptable. Additionally, these units are being used in decentralized wastewater treatment systems, such as surface spray irrigation and subsurface drip dispersal. Advantages include potentially lower capital costs, simple operation, and low Operation and Maintenance (O&M) costs.

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9.1.2 Definitions

"**Director**" means the Director of the Division of Water Resources, Tennessee Department of Environment and Conservation.

"**Division**" means the Division of Water Resources, Tennessee Department of Environment and Conservation.

"**Fault**" means a fracture or a zone of fractures in any material along which strata on one side have been displaced with respect to that on the other side.

"**Floodplain**" means the lowlands and relatively flat areas adjoining inland waters, including flood-prone areas, which are inundated by a flood. The "100-year floodplain" refers to a floodplain that is subject to a one percent or greater chance of flooding in any given year from any source.

"**Karst**" means a specific type of topography that is formed by dissolving or solution of carbonate formations, such as limestone or dolomite; it is characterized by closed contour depressions or sinkholes, caves, sinking and reappearing streams, and/or underground conduit drainage flow.

"**Seismic impact zone**" means an area with a ten percent or greater probability that the maximum horizontal acceleration in lithified earth materials, expressed as a fraction of the earth's gravitational pull will exceed 0.10g in 250 years.

"**Surface impoundment**" means a facility or part of a facility which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials), which is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and which is not an injection well. Examples of surface impoundments are holding, storage, settling and aeration pits, ponds, and lagoons. Surface impoundments will be referred to as "impoundments" in this chapter.

"**Unstable area**" means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the impoundment's structural components responsible for preventing releases from the impoundment. Unstable areas can include poor foundation conditions, areas susceptible to mass movements, and Karst terrains.

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9.2 Engineering Report

In addition to the requirements in Chapter 1, the engineering report (ER) must include an assessment of the hydrogeological and geotechnical characteristics of the site that meets the requirements of these design criteria. The ER should include geotechnical analyses for the dikes and impoundment, including slope stability, seepage, and settlement analyses. These must be performed by a qualified licensed engineer. The ER must be submitted prior to submission of the final construction plans and specifications. The hydrogeological portion of the engineering report must:

1. Be prepared, sealed, signed, and dated by a qualified geologist or a qualified engineer who is licensed or professionally registered with the State of Tennessee as required for such persons at Tennessee Code Annotated section 62-36-102.

2. Be based on an analysis of existing data (e.g., well drillers' logs) and site-specific soil borings and drillers' logs or other subsurface investigations. The soil borings performed must be of such number, locations, and depths to sufficiently provide a complete and accurate description of relevant subsurface conditions.

3. Include a subsurface investigation using generally accepted geophysical methods to investigate potential karst conditions, such as Electrical Resistivity Tomography, Frequency-Domain Electromagnetic, and Seismic Refraction Method (in accordance with American Society of Testing Material (ASTM) D-5777-00). Multiple methods are available and used depending on the site conditions and the purpose of the investigation.

4. Include the following information:

   (i) A description of the soil sampling and analytical procedures used, including a characterization of the soils underlying the site, providing, at a minimum:

      (a) Unified soil classifications;

      (b) The saturated hydraulic conductivities of undisturbed samples of soils underlying the site that is to be used in meeting soil buffer requirements;

      (c) The saturated hydraulic conductivity of remolded samples of soils taken from the site which are to be used in meeting liner and cover requirements; and

(d) A description of the soil sampling and analytical procedures used;

(ii) A tabulation of water table elevations (if encountered within the limits of drillings) measured at the time borings were performed. Groundwater observation wells or piezometers should be installed for monitoring groundwater levels. If an estimation of the seasonal high water table cannot be made utilizing these data and other existing information, then the Division may require water table elevations to be measured over a period of up to one year.

(iii) A boundary plat locating soil borings with accurate horizontal and vertical controls which are tied to a permanent on-site bench-mark (reference elevation may be site-specific). The plat must include the boundary of the proposed fill areas;

(iv) A potentiometric map of the uppermost aquifer (if such can be determined by information obtained within the limits of drilling) based on stabilized water elevations;

(v) A description of local groundwater recharge and discharge features in the vicinity of the proposed impoundment and, if the Division deems appropriate, a description of the regional groundwater regime;

(vi) The locations of any springs and existing and abandoned wells within a one-mile radius;

(vii) The locations of public water supply system intakes and wells within a two-mile radius; and

(viii) A narrative summary and analysis of geological and hydrological evaluations performed as they relate to the suitability of the site for an impoundment.

(ix) The location of the 100-year floodplain near the site.

5. Undisturbed soil samples for hydraulic conductivity must be collected in thin-walled Shelby tubes per ASTM D-1587. The hydraulic conductivity must be determined in accordance with ASTM D-5084.

6. Remolded soil samples for hydraulic conductivity must be re-compacted in accordance with ASTM D-698 [Note: ASTM D-698 (Standard Proctor) is typically used for dikes, dams, and soil liners as opposed to ASTM D-1557 (Modified

Proctor)]. The hydraulic conductivity must be determined in accordance with ASTM D-5084.

7. The report must include a comprehensive environmental site assessment that includes an evaluation of the quality of groundwater beneath the proposed impoundment.

9.3 Stabilization Ponds

Stabilization ponds are facultative and are not artificially mixed or aerated. Mixing and aeration are provided by natural processes. Oxygen is supplied mainly by wind and algae.

9.3.1 Depth

The primary (first in a series) pond depth should not exceed six feet. Greater depths will be considered for polishing ponds and the last ponds in a series of four or more.

9.3.2 Influent Structures and Pipelines

a. Manholes
A manhole should be installed at the terminus of the influent interceptor line or force main and should be located as close to the dike as topography permits; its invert should be at least six inches above the maximum operating level of the pond to provide sufficient hydraulic head without surcharging the manhole. Trash collection (bar screens) as part of the final manhole or headworks shall be provided unless the system is limited to STEP/STEG influent [STEP is septic tank effluent pump; STEG is septic tank effluent gravity].

b. Influent Pipelines

A minimum self-cleaning velocity of three feet per second under normal flow conditions will permit self-cleaning of the pipeline in most circumstances. The influent pipeline can be placed at zero grade if provisions to clean or flush are included. The influent pipeline shall not impede circulation.

c. Inlets and Outlets

Influent and effluent piping should be located to minimize short-circuiting and stagnation within the pond and maximize the use of the entire pond area. There should be a concrete pad for submerged inlets to prevent erosion. The pad should be square with sides equal to three times the pipe diameter.

All gravity lines should discharge horizontally onto discharge aprons. Force mains should discharge vertically up and shall be submerged at least two feet when operating at the one-foot depth.

d. Discharge Apron

Provisions should be made to prevent erosion at the point of discharge to the pond.

9.3.3 Interconnecting Piping and Outlet Structures

Interconnecting piping for pond installations shall be valved or provided with other arrangements to regulate flow between structures and permit variable depth control.

The outlet structure can be placed on the horizontal pond floor adjacent to the inner toe of the dike embankment. A permanent walkway from the top of the dike to the top of the outlet structure is required for access.

The outlet structure should consist of a well or box equipped with multiple-valved pond draw off lines. An adjustable draw off device is also acceptable. The outlet structure should be designed so that the liquid level of the pond can be varied from a three to five-foot depth in increments of 0.5 feet or less. Withdrawal points shall be spaced so that effluent can be withdrawn from depths of 0.75 to two feet below pond water surface, irrespective of the pond depth.

The lowest draw off lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface. A two-foot-deep baffle may be helpful to keep algae from the effluent. The structure should also have provisions for draining the pond. A locking device should be provided to prevent unauthorized access to level control facilities. An unvalved overflow placed six inches above the maximum water level shall be provided.

Outlets should be located nearest the prevailing winds to allow floating solids to be blown away from effluent weirs.

The pond overflow pipes should be sized for the peak design flow to prevent overtopping of the dikes. Other emergency overflow designs may also be acceptable such as an emergency overflow spillway

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9.3.4 Minimum and Maximum Pond Size

No pond should be constructed with less than one-half acre or more than 40 acres of surface area.

9.3.5 Number of Ponds

A minimum of three ponds, and preferably four ponds, in series should be provided (or baffling provided for a single call lagoon design configuration) to provide good hydraulic and kinetic design. The objective of the design is to eliminate short-circuiting and provide full treatment.

9.3.6 Parallel/Series Operation

Designs, other than single ponds with baffling, should provide for the operation of ponds in parallel or series. Hydraulic design should allow for equal distribution of flows to all ponds in either mode of operation.

9.3.7 Design Loading

Design loading should not exceed 30 pounds biochemical oxygen demand (BOD) per acre per day on a total pond area basis and 50 pounds BOD per acre per day to any single pond.

9.4 Aerated Lagoons

9.4.1 Depth

Depth should be based on the type of aeration equipment used, heat loss considerations, and cost, but should be no less than seven feet. In choosing a depth, aerator erosion protection and allowances for ice cover and solids accumulation should be considered.

The minimum operating depth should be sufficient to prevent the growth of aquatic plants and damage to the dikes, bottom, control structures, aeration equipment, and other appurtenances.

a. Controlled-Discharge and Flow-Through Facultative Treatment Pond Systems

The maximum water depth should be six feet in primary cells. Greater depths in subsequent cells are permissible although supplemental aeration or mixing may be necessary.

b. Aerated Treatment Pond Systems

The design water depth should be 10 to 15 feet This depth limitation may be altered depending on the aeration equipment, waste strength, and climatic conditions.

9.4.2 Influent Structures and Pipelines

The same requirements apply as described for facultative systems, except that the discharge locations should be coordinated with the aeration equipment design.

9.4.3 Interconnecting Piping and Outlet Structures

a. Interconnecting Piping.

The same requirements apply as described for facultative systems.

b. Outlet Structure.

The same requirements apply as described for facultative systems, except for variable depth requirements and arrangement of the outlet to withdraw effluent from a point at or near the surface. The outlet shall be preceded by an underflow baffle.

9.4.4 Number of Lagoons

No fewer than three basins should be used to provide the detention time and volume required. The basins should be arranged for both parallel and series operation. A very good design approach is to provide a complete-mix lagoon (detention time = typically, three to four days) followed by two partial-mix lagoons (typically in series operation; detention time in each partial-mix lagoon = six to eight days). A settling pond with a hydraulic detention time of two days at average design flow must follow the aerated cells, or an equivalent of the final aerated cell must be free of turbulence to allow the settling of suspended solids.

Alternative designs may be submitted to the Division for consideration.

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9.4.5 Aeration Equipment

A minimum of two mechanical aerators or blowers shall be used to provide the horsepower required. At least three anchor points should be provided for each aerator. Access to aerators should be provided for routine maintenance which does not affect mixing in the lagoon. Timers will be required.

Either mixing requirements or oxygen requirements will control the amount of aeration equipment used in a lagoon. Mixing requirements have been noted above. Minimum aeration requirements to satisfy oxygen needs in a given lagoon. Assuming that nitrification is not required, can be determined as follows:

$$\text{lb/day } O_2 = (8.34)\ Q\ [1.5(S_o - S_e)]$$

where:

Q = design wastewater flow rate, million gallons per day (mgd)
S_o = lagoon influent BOD_5, mg/L
S_e = lagoon effluent BOD_5, mg/L

Aeration horsepower requirements to satisfy oxygen needs in a lagoon can be calculated as follows:

$$HP = \text{lb/day } O_2 \div [\text{Field OTR x 24 hr/day}]$$

Field OTR = oxygen transfer rate of aerator in lb/(HP-hr) in the field

Mechanical aeration equipment is rated by manufacturers at standard *conditions (tap water; 20°C; 1 atmosphere of pressure; initial DO = 0.0 mg/L). The rated value is called the standard oxygen transfer rate ($OTR_{standard}$ or SOTR), which must be corrected to field conditions by the following equation.*

$$OTR = OTR_{standard}\left[\frac{(\beta\rho C_s - C)}{9.2}\right]1.024^{(T-20)}$$

where:

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C = dissolved oxygen level in the lagoon (typically 1.5 to 2 mg/L)

C_s = saturated dissolved oxygen level in mg/L

α = K_La of wastewater/K_La of tap water; use α = 0.80 to 0.90 unless specified otherwise.

β = C_s wastewater/C_s tap water = 0.92 for municipal wastewater

ρ = factor that corrects for elevation differences; see recommended values of ρ noted below.

Elevation, ft MSL	ρ
1000	0.96
2000	0.93
3000	0.89
4000	0.86
5000	0.83
6000	0.80
7000	0.77
8000	0.74

The horsepower requirements for mixing and oxygen should be compared, and the greater value should be used for the design of the given lagoon. In most cases, mixing requirements will control the aerator design. However, in the first aerated lagoon, oxygen requirements may control the aerator design, depending on raw wastewater organic strength.

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9.5 Pond Features

9.5.1 Pond Shape

The shapes of all cells should be such that there are no narrow, L-Shaped, or elongated portions. Round or rectangular ponds are most desirable. Rectangular ponds with a length not exceeding three times the width are considered most desirable for complete mix aerated lagoons. However, stabilization ponds should be rectangular with a length not exceeding three times the width, or be baffled to ensure full utilization of the basin. No islands, peninsulas, or coves are permitted. Dikes should be rounded at corners to minimize accumulations of floating materials.

9.5.2 Recirculation

Recirculation of lagoon effluent may be considered. Recirculation systems are typically designed for 0.5 to 2.0 times the average influent wastewater flow and include flow measurement and control.

9.5.3 Flow Measurement

The design shall include provisions to measure, total, and record the wastewater flows to meet permit requirements.

9.5.4 Level Gauges

Pond level gauges should be located on outfall structures or be attached to a stationary structure for each pond.

Some impoundments may need to have remote water level monitoring capable of providing a continuous, year-round record of impoundment levels accurate to within 0.125 inches. [Depends on the purpose, design, and permitting requirements].

9.5.5 Pond Dewatering

Sufficient pumps and appurtenances should be available to facilitate the draining of individual ponds in cases where multiple pond systems are constructed at the same elevation or for use if recirculation is desired.

9.5.6 Control Building

A control building for laboratory and maintenance equipment should be provided.

9.5.7 General Site Requirements

The pond area shall be enclosed with an adequate fence to keep out livestock, wildlife, discourage trespassing, and be located so that travel along the top of the dike by maintenance vehicles is not obstructed. A vehicle access gate of a width sufficient to accommodate mowing equipment and maintenance vehicles should be provided. All-access gates shall be provided with locks. Cyclone-type fences, six feet high with three strands of barbed wire at a 45-degree angle to the fence (total height is seven feet), with appropriate warning signs, are required.

9.5.8 Provision for Sludge Accumulation

Influent solids, bacteria, and algae that settle out in the lagoons will not completely decompose and a sludge-blanket will form. This can be a problem if the design does not include provisions for the removal and disposal of accumulated sludge, particularly in the cases of anaerobic stabilization ponds and aerated lagoons. The design should include an estimate of the rate of sludge accumulation, frequency, or sludge removal, methods of sludge removal, and ultimate sludge handling and disposal.

9.5.9 Risk Assessment

Ponds and lagoons should be assessed with respect to the degree of risk relative to hazards that may be posed in the event of accidental or catastrophic release. [Note: a **hazard** is something that can cause harm, e.g., electricity, chemicals, noise, etc. A **risk** is the chance, high **or** low, that any **hazard** will actually cause somebody harm]. These criteria focus on the operability and maintainability of a functioning system and are not geared or focused on preventing structural failures—that is the fiduciary responsibility of the design engineer.

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9.6 Pond Construction

9.6.1 Pond Site Geotechnical Survey

A geotechnical survey must be done to determine the site's appropriateness and a design to meet the criteria developed by a geotechnical engineering firm.

9.6.2 Pond Seal

Ponds must be sealed such that seepage loss through the seal is as low as practicably possible (approximately 500 gallons per acre per day). To achieve an adequate seal in a pond/lagoon system using soil, native clay, bentonite-amended soil, geosynthetic clay liners, and geomembranes may be considered, provided the permeability, durability, and integrity of the proposed material can be satisfactorily demonstrated for all anticipated conditions. Results of a testing program that substantiates the adequacy of the proposed seal must be incorporated into and/or accompany the engineering report. Standard ASTM International procedures must be used for all tests. Methods or procedures not covered by ASTM must be approved in advance by TDEC-Division of Water Resources (DWR). The permeability or hydraulic conductivity (k) in centimeters per second specified for the seal must not exceed the value derived from the following expression:

$$k = FL$$

Where,

L = seal/liner thickness (cm), and

F = constant 3.0×10^{-9} sec^{-1}

For water balance calculations, note that permeability and seepage rates per unit area differ and that Darcy's seepage rate is not *k,* but it is a function of *k*. To calculate the seepage rate use Darcy's Law as follows:

$$Q = \frac{kAh}{L}$$

Where,

k **=** permeability, cm/sec;

L = seal/liner thickness (cm);

Q = flow through the liner, cm^3/sec;

A = liner area, cm^2; and

h = hydraulic head over the line, cm.

The design of the liner either clay, clay + geotechnical liner, or geotechnical liners must take into account the depth of water and the local conditions and provide a specification for the liner material and its placement and QC requirements. The geotechnical engineer must be on site frequently enough to modify the design to account for excavation discoveries.

[See Appendices 9-B and 9-C for hydraulic values and conversion factors]

9.6.3 Pond Erosion Control

To prevent erosion and desiccation of clay or bentonite liners, the interior slopes of the lagoon should have soil cover and riprap. Recommended minimums are 1.6 feet above and below the lagoon water level or twice the impinging wave height calculated for twice the maximum wind velocity anticipated. With surface aerators, consideration must be given to protect the basin directly below the aerators from the vortex or other scouring action. Concrete pads, anti-erosion plates on the aerator, or 150 mm (six inches) of crushed rock provides adequate protection. Essentially, the walls must be protected from erosion; the bottom must be protected from damaging scour from inflow, outflow and/or a mechanical mixing or aeration or both. Additional recommendations of the geotechnical engineer must be the followed

Sample wells on the dike or berm in strategic locations (at least two and one more for each acre above one acre for lagoons less than six feet to overflow or operating level and twice that number of operating depths greater than six feet). Emergency overflows with flow measurement and disinfection for overflows must be provided.

9.6.4 Pond Embankment

Embankment tops of a minimum width of 2.5 meters (eight feet) permit access of maintenance vehicles. The embankment's outer slopes should be no steeper than 3:1 to allow grass growth and tractor mowing. During construction, the QC, testing, and results over the expanse of the lagoon + two feet of freeboard on the walls shall be witnessed by a registered geotechnical engineer.

9.6.5 Pond Inspections

Structural inspections by a registered geotechnical engineer should be conducted every five years at a minimum to ensure integrity, or more frequently if seepage, erosion, or cracks on the berm surface appear. Action must be taken in accordance with the recommendations made by the geotechnical engineer in the structural integrity evaluation. Sampling wells must be sampled and water depths recorded as part of this integrity evaluation.

APPENDIX 9-A

BIBLIOGRAPHY – CHAPTER 9

1. *Recommended Standards for Wastewater Facilities* (Policies for the Design, Review, and Approval of Plans and Specifications for Wastewater Collection and Treatment Facilities) 2014 Edition [A Report of the Wastewater Committee of the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers] Member U.S. States and Canadian Province: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, Wisconsin. (Published By: Health Research Inc., Health Education Division, Albany, NY).
2. *Design of Municipal Wastewater Treatment Plants* (Chapter 13 Natural Systems), Fourth Edition, MOP-8, Water Environment Federation 1998.
3. *Design of Water Resource Recovery Facilities* (Chapter 16 Natural Systems) Sixth Edition, MOP-8, Water Environment Federation 2018.
4. *Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers.* EPA/600/R-11/088, August 2011.
5. *Design Manual for Municipal Wastewater Stabilization Ponds.* EPA-625/1-83-015, October 1983.
6. Middlebrooks, E.J., et al. *Wastewater Stabilization Lagoon Design, Performance and Upgrading*, (McMillan Publishing Co., New York, NY) 1982.
7. Stone, Nathan M., and Claude E. Boyd. Alabama Agricultural Experiment Station Bulletin 599. Auburn University Alabama. *Seepage from Fishponds.* 1989.

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APPENDIX 9-B

Comparison of 10 States Standards and WEF MOP-8

FROM 10 STATES STANDARDS:

To achieve an adequate seal in a pond/lagoon system using soil, native clay, bentonite-amended soil, or other seal materials, the permeability or hydraulic conductivity (k) in centimeters per second specified for the seal shall not exceed the value derived from the following expression:

$$k = FL$$

Where,

L = seal/liner thickness (cm), and

F = constant 2.6×10^{-9} sec^{-1}

Therefore, at L = 30.48 cm (1 foot):

$k = 2.6 \times 10^{-9}\ sec^{-1} \times 30.48\ cm$

$k = 79.25 \times 10^{-9}$ cm/sec

FROM WEF MOP-8:

Uses basically the same expression as 10 States Standard, except for F

$$k = FL$$

Where,

L = seal/liner thickness (cm), and

F = constant 3.0×10^{-9} sec^{-1}

For water balance calculations, note that permeability and seepage rates per unit area differ and that Darcy's seepage rate is not k, but it is a function of k. To calculate the seepage rate, use Darcy's Law as follows:

$$Q = \frac{kAh}{L}$$

Where,

k = permeability, cm/sec;

L = seal/liner thickness (cm);

Q = flow through the liner, cm^3/sec;

A = liner area, cm^2; and

h = hydraulic head over the line, cm.

FROM WEF MOP-8:

$$Q = \frac{kAh}{L}$$

For ***h*** = 6 feet:

$$Q = \frac{(79.25 \times 10^{-9}\ \text{cm/sec})(43{,}560\ \text{ft}^2/\text{ac})(6\ \text{ft})(7.48\ \text{gal/ft}^3)(1{,}440\ \text{min/day})(60\ \text{sec/min})}{1\ \text{ft}\ (30.48\ \text{cm/ft})}$$

Q = 439.18 GPD/acre (using F = 2.6×10^{-9} sec^{-1} per 10 States Standards)

If F = 3.0×10^{-9} sec^{-1}, per MOP-8, then:

Q = 507 GPD/acre

[Note: 10 States Standards says that Q should be less than 500 GPD/acre]

Seepage Rate =
(507 gal/ac-day)(ft^3/7.48 gal)(acre/43,560 ft^2)(12 in/ft)(2.54 cm/in)(day/1,440 min)(min/60 sec)

= 5.5×10^{-7} cm/sec

@439.18 GPD/acre, Seepage Rate = 4.8×10^{-7} cm/sec

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APPENDIX 9-C

Hydraulic Values and Conversion Factors

0.2 gallons per day per square foot (GPD/SF) = 2.25 inches per week (in/wk)

0.18 GPD/SF = 2.00 inches/week

0.13 GPD/SF = 1.5 inches/week

0.11 GPD/SF = 1.25 inches/week

0.10 GPD/SF = 1.12 inches/week

Moderately Slowly Permeable @ 0.2 inch/hour x 10% = 3.4 inches/week

Slowly Permeable @ 0.06 inch/hour x 10% = 1.0 inch/week

0.25 GPD/SF = 2.81 inches/week = 0.4 inch/day = 10,899 GPD/ac

1.0 inch/week = 0.089 GPD/SF = 3,880 GPD/ac

500 GPD/ac = 0.128 inches/week

0.1 GPD/SF = 4.7 x 10^{-6} cm/sec

0.25 inch/day = 6,788 GPD/ac

The maximum allowable seepage rate is 0.0015 feet per day or 500 gallons per acre per day.

The following soil types, based upon the Unified Soil Classification System groups, have published (4) seepage rates greater than 0.0015 feet/day.

- CL (low to medium plasticity clays)
- GC (clayey gravels and poorly graded gravel-sand-clay mixtures)
- GM (silty gravel and poorly graded gravel/sand-silt mixtures)
- GP (poorly graded gravels and sandy gravel mixtures with little or no fines)
- GW (well-graded gravels and gravel-sand mixtures)
- ML (inorganic silts - very fine sands, silty, or clayey fine sands)
- SC (clayey sands, sand clay mixtures)
- SM (silty sand, sand silt mixtures)
- SP (poorly graded sands and gravelly sands with little or no fines)
- SW (well-graded sands and gravelly sands with little or no fines)

Therefore, these soils by themselves are unacceptable without a synthetic liner or other construction modifications to reduce seepage. However, CH (high plasticity clays) with a listed seepage rate of 0.0003 feet per day would be acceptable.

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APPENDIX 9-D-1

ENGINEERING REPORT
IMPOUNDMENTS, PONDS, AND AERATED LAGOONS
REVIEW GUIDANCE – CHECKLIST

WPN: _________________ **PROJECT:________________________________**

Acceptable	Item Number	DESCRIPTION	COMMENTS
		General	
☐	**1**	In addition to the requirements in Chapter 1, the engineering report (ER) must include an assessment of the hydrogeological and geotechnical characteristics of the site that meets the requirements of these design criteria. The ER should include geotechnical analyses for the dikes and impoundment, including slope stability, seepage, and settlement analyses. These must be performed by a qualified licensed engineer. The ER must be submitted prior to submission of the final construction plans and specifications.	
		Hydrogeological Portion of ER	
☐	**2**	Must be prepared, sealed, signed, and dated by a qualified geologist who is licensed with the State of Tennessee as required for such persons at Tennessee Code Annotated section 62-36-102.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Hydrogeological Portion of ER			
☐	**3**	Findings must be based on an analysis of existing data (e.g., well drillers' logs) and site-specific soil borings and drillers' logs or other subsurface investigations. The soil borings performed must be of such number, locations, and depths to sufficiently provide a complete and accurate description of relevant subsurface conditions.	
☐	**4**	Must include a subsurface investigation using generally accepted geophysical methods to investigate potential karst conditions, such as Electrical Resistivity Tomography, Frequency-Domain Electromagnetic, and Seismic Refraction Method (in accordance with ASTM D-5777-00). Multiple methods are available and used depending on the site conditions and the purpose of the investigation.	
☐	**5**	Provide a description of the soil sampling and analytical procedures used including, but not necessarily limited to, a characterization of the soils underlying the site.	
☐	**6**	Provide unified soil classifications.	
☐	**7**	Provide the saturated hydraulic conductivities of undisturbed samples of soils underlying the site that is to be used in meeting soil buffer requirements.	
	8	Provide the saturated hydraulic conductivity of remolded samples of soils taken from the site which are to be used in meeting liner and cover requirements.	
	9	Provide a description of the soil sampling and analytical procedures used.	

Acceptable	Item Number	DESCRIPTION	COMMENTS
Hydrogeological Portion of ER			
☐	**10**	Provide a tabulation of water table elevations (if encountered within the limits of drillings) measured at the time borings were performed. Groundwater observation wells or piezometers should be installed for monitoring groundwater levels. If an estimation of the seasonal high water table cannot be made utilizing these data and other existing information, then the Division may require water table elevations to be measured over a period of up to one year.	
☐	**11**	Provide a boundary plat locating soil borings with accurate horizontal and vertical controls which are tied to a permanent on-site bench-mark (reference elevation may be site-specific). The plat must include the boundary of the proposed fill areas.	
☐	**12**	Provide a potentiometric map of the uppermost aquifer (if such can be determined by information obtained within the limits of drilling) based on stabilized water elevations.	
☐	**13**	Provide a description of local groundwater recharge and discharge features in the vicinity of the proposed impoundment and, if the Division deems appropriate, a description of the regional groundwater regime.	
☐	**14**	Provide the locations of any springs and existing and abandoned wells within a one-mile radius.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Hydrogeological Portion of ER			
	15	Provide the locations of public water supply system intakes and wells within a two-mile radius.	
	16	Provide a narrative summary and analysis of geological and hydrological evaluations performed as they relate to the suitability of the site for an impoundment, and address in particular compliance with appropriate standards of these criteria	
	17	Show the location of the 100-year floodplain near the site.	
	18	Undisturbed soil samples for hydraulic conductivity must be collected in thin-walled Shelby tubes per ASTM D-1587. The hydraulic conductivity must be determined in accordance with ASTM D-5084	
	19	Remolded soil samples for hydraulic conductivity must be re-compacted in accordance with ASTM D-698 [Note: ASTM D-698 (Standard Proctor) is typically used for dikes, dams, and soil liners as opposed to ASTM D-1557 (Modified Proctor)]. The hydraulic conductivity must be determined in accordance with ASTM D-5084.	
	20		

APPENDIX 9-D-2

FINAL DESIGN SUBMISSION
FOR
IMPOUNDMENTS, PONDS, AND AERATED LAGOONS
REVIEW GUIDANCE – CHECKLIST

WPN: __________________ **PROJECT:_________________________________**

Acceptable	Item Number	DESCRIPTION	COMMENTS
		General	
☐	1	Accurately completed Wastewater Plans Review Fee Worksheet (CN-1457)	
☐	2	Cover letter and/or plan signed by utility representative and/or letter provided by the utility stating they approve the design and will own, operate, and maintain the improvements.	
☐	3	Check received for the correct amount	
☐	4	All plan sheets sealed by a professional engineer licensed in TN, signed by owner; legible when printed on an 11x17 sheet	
☐	5	Calculations including all information required by Section 9.2 sealed by a professional engineer licensed in TN	
☐	6	Other utilities shown on plan and profile sheets	
☐	7	Project cost	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Stabilization Ponds			
☐	**8**	Design loading should not exceed 30 pounds BOD per acre per day on a total pond area basis and 50 pounds BOD per acre per day to any single pond.	
☐	**9**	The primary (first in a series) pond depth should not exceed six feet. Greater depths will be considered for polishing ponds and the last ponds in a series of four or more.	
☐	**10**	A manhole should be installed at the terminus of the influent interceptor line or force main and should be located as close to the dike as topography permits; its invert should be at least six inches above the maximum operating level of the pond to provide sufficient hydraulic head without surcharging the manhole.	
	11	A minimum self-cleaning velocity of three feet per second under normal flow conditions will permit self-cleaning of the pipeline in most circumstances. The influent pipeline can be placed at zero grade if provisions to clean or flush are included. The influent pipeline shall not impede circulation.	
	12	Influent and effluent piping should be located to minimize short-circuiting and stagnation within the pond and maximize the use of the entire pond area. There should be a concrete pad for submerged inlets to prevent erosion. The pad should be square with sides equal to three times the pipe diameter.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Stabilization Ponds			
☐	**13**	All gravity lines should discharge horizontally onto discharge aprons. Force mains should discharge vertically up and shall be submerged at least two feet when operating at the one-foot depth.	
☐	**14**	Provisions should be made to prevent erosion at the point of discharge to the pond.	
☐	**15**	Interconnecting piping for pond installations shall be valved or provided with other arrangements to regulate flow between structures and permit variable depth control.	
	16	The outlet structure should consist of a well or box equipped with multiple-valved pond draw off lines.	
	17	The lowest draw off lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface.	
	18	The pond overflow pipes should be sized for the peak design flow to prevent overtopping of the dikes.	
	19	No pond should be constructed with less than one-half acre or more than 40 acres of surface area.	
	20	A minimum of three ponds, and preferably four ponds, in series should be provided (or baffling provided for a single call lagoon design configuration) to provide good hydraulic and kinetic design.	
	21	Designs, other than single ponds with baffling, should provide for the operation of ponds in parallel or series. Hydraulic design should allow for equal distribution of flows to all ponds in either mode of operation.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Aerated Lagoons			
☐	22	Depth should be based on the type of aeration equipment used, heat loss considerations, and cost, but should be no less than seven feet. In choosing a depth, aerator erosion protection and allowances for ice cover and solids accumulation should be considered.	
☐	23	The maximum water depth should be six feet (1.8 meters) in primary cells. Greater depths in subsequent cells are permissible although supplemental aeration or mixing may be necessary.	
☐	24	The design water depth should be 10 to 15 feet (3.0 to 4.6 meters). This depth limitation may be altered depending on the aeration equipment, waste strength, and climatic conditions	
☐	25	No fewer than three basins should be used to provide the detention time and volume required. The basins should be arranged for both parallel and series operation.	
☐	26	A settling pond with a hydraulic detention time of two days at average design flow must follow the aerated cells, or an equivalent of the final aerated cell must be free of turbulence to allow settling of suspended solids.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
		Aerated Lagoons	
☐	**27**	A minimum of two mechanical aerators or blowers shall be used to provide the horsepower required. At least three anchor points should be provided for each aerator.	
☐	**28**	Round or rectangular ponds are most desirable. Rectangular ponds with a length not exceeding three times the width are considered most desirable for complete mix aerated lagoons.	
☐	**29**	Minimum aeration requirements to satisfy oxygen needs in a given lagoon. Assuming that nitrification is not required, can be determined as follows: lb/day $O_2 = (8.34)\ Q\ [1.5(S_o - S_e)]$ where: Q = design wastewater flow rate, million gallons per day (mgd) S_o = lagoon influent BOD_5, mg/L S_e = lagoon effluent BOD_5, mg/L	
☐	**30**	The horsepower requirements for mixing and oxygen should be compared, and the greater value should be used for the design of the given lagoon. In most cases, mixing requirements will control the aerator design. However, in the first aerated lagoon, oxygen requirements may control the aerator design, depending on raw wastewater organic strength.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Aerated Lagoons			
☐	**31**	Recirculation of lagoon effluent may be considered. Recirculation systems are typically designed for 0.5 to 2.0 times the average influent wastewater flow and include flow measurement and control.	
☐	**32**	The design shall include provisions to measure, total, and record the wastewater flows to meet permit requirements.	
☐	**33**	Pond level gauges should be located on outfall structures or be attached to a stationary structure for each pond.	
☐	**34**	Some impoundments may need to have remote water level monitoring capable of providing a continuous, 24-hour per day, 365 days, record of impoundment levels accurate to within 0.125 inches. [Depends on the purpose, design, and permitting requirements].	
☐	**35**	Sufficient pumps and appurtenances should be available to facilitate the draining of individual ponds in cases where multiple pond systems are constructed at the same elevation or for use if recirculation is desired.	

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Acceptable	Item Number	DESCRIPTION	COMMENTS
Pond Construction			
☐	**36**	A geotechnical survey must be done to determine the site's appropriateness and a design to meet the criteria developed by a geotechnical engineering firm.	
☐	**37**	Ponds must be sealed such that seepage loss through the seal does not exceed approximately 500 gallons per acre per day. Results of a testing program that substantiates the adequacy of the proposed seal must be incorporated into and/or accompany the engineering report. Standard ASTM The permeability or hydraulic conductivity (*k*) specified for the seal must not exceed the value derived from the following expression: ***k* = FL,** where **L** = seal/liner thickness (cm), and **F** = constant 3.0×10^{-9} sec^{-1}	
☐	**38**	The design of the liner either clay, clay + geotechnical liner, or geotechnical liners must take into account the depth of water and the local conditions and provide a specification for the liner material and its placement and QC requirements.	
☐	**39**	To prevent erosion and desiccation of clay or bentonite liners, the interior slopes of the lagoon should have soil cover and riprap.	
☐	**40**	Minimum width of embankment tops is eight feet	

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