NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD
ARIZONA

POND SEALING OR LINING – FLEXIBLE MEMBRANE

(No.)

CODE 521A

DEFINITION

A manufactured hydraulic barrier consisting of a functionally continuous layer of synthetic or partially synthetic, flexible material.

PURPOSE

To restrict, impede, and control seepage of contaminants from water and waste impoundment structures for water conservation and environmental protection.

CONDITIONS WHERE PRACTICE APPLIES

This practice may be applied as part of a conservation management system to support the following:

- On ponds and water storage structures that require treatment to control seepage rates within acceptable limits.
- On earthen waste storage *or treatment* lagoons and other waste impoundment structures that require treatment to control seepage of contaminants from the storage structure.

This practice has been determined to have no effect on federally listed species if installed outside of the designated 100-year flood plain. Additional determination of effect by NRCS and consultation with the Fish and Wildlife Service may be required for installation within the 100-year floodplain.

CRITERIA

Structures and/or facilities shall be designed on an individual basis to meet site conditions and functional requirements. They shall be part of an approved and overall engineering plan for irrigation, drainage, wildlife, recreation, channel improvement, or similar purposes.

Design and implementation of subsidiary components and/or structures shall meet all applicable Natural Resource Conservation Service (NRCS) conservation practice standards. The criteria for the design of any components not specifically addressed in NRCS practice standards or specifications shall be consistent with sound engineering principles and/or manufacturer recommendations.

Laws and Regulations*. All federal, State, Tribal and local laws, rules, regulations, and requirements shall be addressed in the planning and design of this practice. Laws and regulations of particular concern include those involving water rights, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.*

The owner is responsible for securing necessary permits and water rights, complying with all laws and regulations, and meeting legal requirements applicable to the installation, operation, and maintenance of this practice and associated structures.

Design. Structures to be lined shall have been constructed to meet all applicable *Natural Resources Conservation Service (*NRCS*)* standards. All inlets, outlets, ramps, and other appurtenances may be installed before, during, or after the liner placement, but shall be done in a manner that does not

damage or impair the proper operation of the liner.

Design and installation of the flexible membrane shall be in accordance with manufacturer recommendations. *Design liner material to meet the minimum requirements in Table 1.* All flexible membrane installations shall be certified by the installer as meeting the material and installation requirements of the plans and specifications*, and all warranty requirements*.

All flexible membranes shall be certified by the manufacturer to be suitable for the intended use.
Manufacturer recommendations shall be followed with regard to protection from weather and exposure.

Table 1 Minimum Liner Criteria

Minimum Geomembrane Thickness Criteria		
Type [1/]	**Minimum Thickness**	
	Wastewater	Clear Water
HDPE	40 mil [2/]	30 mil
LLDPE	40 mil	30 mil
LLDPE-R	36.mil	24 mil
PVC	40 mil	30 mil
EPDM	45 mil	
FPP	40 mil	30 mil
FPP-R	36 mil	24 mil
PE-R	NR	24 mil

Minimum Bentonite Content for Geosynthetic Clay Liners		
Type	**Minimum Bentonite Content**	
	Wastewater	Clear Water
GCL	0.75 lb/sq. ft.	

[1/] HDPE – High Density Polyethylene Geomembrane
LLDPE – Linear Low Density Polyethylene Geomembrane
LLDPE-R - Reinforced Linear Low Density Polyethylene Geomembrane
PVC – Polyvinyl Chloride Geomembrane
EPDM – Ethylene Propylene Diene *TerpolyMer* Geomembrane
FPP – Flexible Polypropylene Geomembrane
FPP-R – Reinforced Flexible Polypropylene Geomembrane
PE-R – Reinforced, Slit –Film, Woven Polyethylene Geomembrane
NR – Not Recommended
GCL – Geosynthetic Clay Liner
[2/] 1 mil = 1/1000 of an inch

Reference Specifications for Geomembranes	
Type	**Applicable Specification**
HDPE	MS-AZ-594_Flexible Membrane Liner
LLDPE	
LLDPE-R	
PVC	
EPDM	
FPP	
FPP-R	
PE-R	

Reference Specifications for Geosynthetic Clay Liners	
Type	**Applicable Specification**
GCL	MS-AZ-595_Geosynthetic Clay Liner

Cover Soil. PVC and GCL liners shall be covered with a minimum of 12 inches of soil measured perpendicular to the finished surface. Cover soil may be used on other liners but is not required unless essential for the proper performance, protection and durability of the installation. Cover soils shall not contain sharp, angular stones or any objects that could damage the liner. Maximum allowable particle size of soil cover material shall be 3/8-in for geomembrane liners and ½-inch for geosynthetic clay liners, unless the liner is protected by a 10-oz/sq yd or heavier non-woven geotextile cushion material. Cover materials shall be stable against slippage down the slope under all operational and exposure conditions, such as rapid

drawdown or saturation by precipitation or snowmelt.

Cover soil shall be placed within 24 hours after placement of the liner to minimize the potential for damage from various sources, including precipitation, wind, and ultra-violet exposure.

GCL liners shall have a uniform confinement pressure as recommended by the manufacturer, which shall not be compromised by the presence of a drainage layer or venting system under the liner.

Where concrete is to be placed over-exposed liners, an 8-ounce or greater nonwoven geotextile or an additional layer of liner shall be placed between the concrete and the liner. The geotextile or additional layer of liner shall extend at least 6 inches beyond the concrete edges.

***Slopes**. All banks and slopes to be lined with PVC and GCL liners shall be sloped no steeper than 3:1. All other liner types may be placed on slopes no steeper than 2:1. Slope the bottom of the pond towards the sides, at a minimum of 0.005 feet/feet, to allow migration of any gas from beneath the liner.*

In the absence of defined design documentation or manufacturer recommendations, side slope selection may be determined by the Factor of Safety (FOS) and a side slope from Table 2. Select a liner material soil cover type combination from Table 3 that has a higher friction angle than selected in Table 2.

Table 2 – Required cover soil friction angles for various slopes and factors of safety (FOS)

Slope Ratio (H:V)	*Required Cover Soil Friction Angle, FOS=1.5*	*Required Cover Soil Friction Angle, FOS=2.0*
1:1	*56*	*n/a*
1.5:1	*45*	*53*
2:1	*36*	*45*
2.5:1	*31*	*39*
3:1	*26*	*34*
4:1	*20*	*26*

Table 3 – Friction angles for various soil and liner materials

	ML-CL	*CL-ML*	*CL*	*SP-CH*	*CL-SP*
	Coefficient of Internal Friction, degree				
Soil-to-soil	*38*	*34*	*30*	*24*	*22*
Geomembrane-to-soil	*Friction Angle Between Soil and Liner, degree*				
PVC	*39*	*23*	*16*	*24*	*17*
CPE	*40*	*24*	*17*	*23*	*19*
EPDM	*33*	*23*	*23*	*20*	*18*
HDPE	*26*	*23*	*15*	*21*	*15*
Embossed HDPE	*35*	*29*	*27*	*26*	*25*

Subgrade Preparation. Subgrade preparation shall conform to manufacturer recommendations and applicable state regulations. Subgrade materials shall not contain sharp, angular stones or any objects that could damage the liner or adversely affect its function unless a cushion layer is used. *The subgrade surface shall be rolled with a smooth drum roller prior to liner placement.*

Cushion A cushion layer shall be placed beneath the liner if the subgrade particles contain sharp angular stones that could damage the liner or particles greater than 3/8-inch for geomembrane liners and ½-inch for GCL's. The cushion may be a 10-oz/sq yd or heavier non-woven geotextile or a layer at least 6 inches thick of soil meeting the particle size and shape requirements of the subgrade. Geotextile cushion material shall meet the requirements of GRI Test Method GT12(a). Follow the manufacturer's recommendations for any additional protective measures.

Anchorage. Liners shall be anchored to prevent uplift due to wind or slippage down the side slope. *Anchor trenches shall have a*

minimum width and depth of 2 feet and shall be located at least 3 feet from the top edge of the pond. Liner material is to be installed down the pond side of the trench and across the bottom. Other trench configurations shall be designed to provide pull out resistance equivalent to the 2-foot deep trench stated above.

***Seams**. Construct seams according to manufacturer's recommendations and test to assure water tightness. Place the bottom of the liner a minimum of one foot above seasonal high water table when used in a manure storage or treatment facility.*

Safety. Design shall include appropriate safety features to minimize the hazards of the structure. Warning signs, fences, ladders, ropes, bars, rails, and other devices shall be provided, as appropriate, to ensure the safety of humans and livestock. *All structures shall be fenced to protect the liner from damage and for the safety of humans, livestock, wildlife, and pets.*

Underliner Drainage and Venting. Subsurface conditions such as soil type and groundwater levels will dictate the direction and scope of the design of the drainage and venting system beneath the geomembrane liner. An inadequate drainage and venting system may result in floating of the geomembrane liner. Hydrostatic pressures from fluctuating groundwater levels or leakage through the liner may cause the liner to float. Gas production and buildup beneath the liner due to the presence of organic material in the soil or leachate leakage through the liner may cause "whales" or bubbling of the liner.

Groundwater and Leakage Drainage. If the groundwater level may be near the invert elevation of the pond, groundwater monitoring should be conducted during the site investigation to verify the expected water table location. In some situations, it may be necessary to install groundwater monitoring wells for a year or more to determine the ground water levels and gather enough information to properly determine the required flow capacity of the drainage system. If high water tables could adversely affect the proper functioning of the structure, interceptor or relief-type drainage systems should be included to control uplift pressures. Leakage through the liner due to liner damage should also be considered. Giroud and Bonaparte (1989) recommend designing the drainage system based on a frequency of one hole (0.16 in^2) per acre of surface area.

Gas Venting. The need for venting for wastewater pond liners shall be investigated as part of the design. Site conditions which may be conducive to gas production include sites which have been subject to long-term seepage of animal waste into the foundation soil, sites with naturally occurring organics in the soil, or fine grained foundation soils where fluctuating groundwater levels may trap gases present in the soil. Venting of wastewater pond liners may not be required if other site conditions exist to allow dissipation of gas pressure from beneath the liner. One such condition is the presence of clean granular foundation soils (SW, SP, GW or GP).

Drainage and Venting System Design. The use of a geosynthetic such as a geonet or geocomposite under the liner to facilitate collection, drainage of liquids and venting of gas should be considered. If drainage and/or venting is needed, the geocomposite manufacturer's recommendations shall be followed in the system design. The allowable flow rate of the geocomposite shall be determined in accordance with GRI Standard GC8. The pond bottom should be sloped, typically a minimum of 1 percent, to permit positive flow of the liquids or gases. In most cases, the geocomposite will serve both purposes of drainage and venting. In large impoundments, the bottom may need to be sloped in multiple directions in order to decrease the required drainage and venting flow travel distances.

Investigations, Surveys and Design Criteria. *Documentation requirements will be as outlined below, in additional to the documentation requirements of the practice components used in the system.*

Make a preliminary site assessment or reconnaissance to determine if the practice is feasible, considering the field or system layout, soils, crops, topography, water supply, and may include:

1. *Soil borings, geological site investigation or soil survey, depending on existing site conditions or scope and complexity and to determine foundation materials or conditions or soil limitations (Soil classification by the Unified Soil Classification System).*
2. *Lining material selection, or alternatives.*
3. *Verify appropriate state laws for permitting and notify landowner of his/her responsibilities.*
4. *Verification or certification of used materials (if any).*

To adequately plan and layout this practice, a detailed topographic survey is required, that adequately details:

1. *Site topography, as needed to show the practice and component layout, physical features of the site (field boundaries and slope), including existing features/practices, ground elevations (slopes), location of any utilities or markers, etc.*
2. *Profiles and cross sections, as required to determine location, material quantities/sources, etc. Survey shall extend 100 feet (minimum) beyond the limits of the proposed lining;*
3. *If applicable, a permanent benchmark(s) may be set and described. Preferably, the elevations and coordinates should be based on a local (assumed) or coordinate system (State or grid) and clearly stated on the plan. Datum may be in the form of Northing and Easting coordinates or Longitude and Latitude.*

The design of a practice is the application of Field Office Technical Guide practice standards, and using experience and judgment in the development of a solution to the problem or the objective. All computations and decisions made during the design of a practice are to be checked by another qualified individual and appropriate notations made. Design computations, calculations or analysis shall meet the following criteria:

1. *Determine the size, type and lining material properties (thickness), including foundation or subgrade preparation requirements.*
2. *Include estimates of earthwork, pipe, fittings and appurtenances, concrete, vegetative components, etc.*
3. *Subsidiary and applicable components shall be designed in accordance with applicable conservation practice standards (i.e., pipelines shall meet the requirements of Conservation Practice 430 – Irrigation Pipeline, etc.);*

Installation and Basis of Acceptance*.*
For construction that does not meet State, OSHA, or Tribal criteria or requirements where deficient construction materials were used, NRCS may consider a waiver request for approval of construction after it has received a signed and sealed construction and/or material exemption from a licensed engineer. Required exemption shall be for installation of materials that do not meet minimum quality criteria as found in applicable Standards, Specifications, ASTM's, AWWA standards, etc.

Contractors performing work under this practice shall abide by all Federal, State or Tribal laws or criteria, and must be licensed by the state DWR or board of technical registers where the work is being implemented.

CONSIDERATIONS

The number of penetrations through the liner should be minimized. Trenching and backfilling of fill pipes should be detailed

such that charging of the underside of the liner with subsurface water is prevented.

For GCL liners, wastewater and subgrade and cover soils should be analyzed to ensure that undesirable cation exchange (calcium and/or magnesium for sodium) will not occur in the GCL.

A leak detection system is recommended beneath all liners, especially geomembranes.

If agitation operations may result in abrasion or other mechanical damage to the liner, then protective measures should be provided as needed to ensure the integrity of the liner, such as increasing the liner thickness above the minimum values indicated above or providing protective ramps and aprons at agitation locations.

Sites with the potential for gas buildup require provisions to transfer gas to vents located along the pond perimeter. These provisions shall include:

1. *Underlayment of 8-ounce or greater nonwoven geotextile or approved equivalent,*
2. *Graded pond bottom across the width at a minimum slope of 1%, and*
3. *Vent outlets need to be located high enough to prevent entrance of water during pond overflow conditions.*

The bottom of the waste storage pond shall be a minimum of 4 feet above the seasonal high water table. The seasonal water table may be lowered if the following conditions are met:

1. *A locally perched water table exists. The pond shall not be installed in a regional water table.*
2. *The permeability of the water-bearing material is less than 6 inches per hour and has little potential to serve as a source for either domestic or commercial use.*
3. *Inclusions or localized lenses of coarse-grained material are permitted if they are contained within a soil unit with permeabilities of less than 6 inches per hour, i.e., sand lenses in glacial till.*

The effects of temporary tailwater on the perimeter drain outlet shall be considered. When a perimeter drain system is installed, provisions shall be provided to allow monitoring of the drainage water.

Establishing vegetation on disturbed areas shall be in accordance with NRCS Conservation Practice Standard Critical Area Planting, Code 342. Where conditions preclude or make it difficult to establish vegetative cover, consider using non-vegetative coverings such as rock, geoweb, gabions, or other type of protection.

In highly visible public areas and those associated with recreation, careful considerations should be given to landscape resources. Landforms, structural materials, water elements, and plant materials should visually and functionally complement their surroundings. Exposed concrete surfaces may be formed to add texture or finished to reduce reflection and to alter color contrast. Site selection can be used to reduce adverse impacts or create desirable focal points.

Design alternatives presented to the client should address economics, ecological concerns and acceptable level of risk for design criteria as it relates to hazards to life or property.

PLANS AND SPECIFICATIONS

Development of plans and specifications *will be guided by the National Engineering Handbook, Part 650, the Engineering Field Handbook, Chapter 5, and shall be in accordance with the National Engineering Manual, Parts 541 and 542,* shall be prepared for specific field sites in accordance with this standard and shall describe the *details and* requirements *of planned location, materials, and construction requirements* for applying *or installing* the practice to achieve its intended

uses. As a minimum, the plans and specifications shall provide the following:

1. Project location map, including section, township and range, North arrow, cooperator/owner acknowledgement and certification signature blocks, engineering job class (cover sheet);

2. References that the owner/cooperator are responsible for all permits, rights-of-way, easements and the contact, coordination and location determination of any existing utilities or clearances (buried utility disclaimer);

3. If applicable, a map showing the location of the practice(s) or system in reference to a known or established benchmark or reference point with the location, description and elevation clearly shown. Topographical features and/or controls shall be shown, showing tie in with existing or other planned practices;

4. *Overall system plan view, i.e,* Layout of the containment structure, collection points, waste transfer locations or pipelines, and topography of the site

5. Required liner properties, cushion materials, and pipeline materials *including details of the type and quality.,*

6. Subgrade details, including tolerances on smoothness of the finished grade

7. Details of liner installation, seaming requirements, and requirements for attachments and appurtenances

8. Minimum qualifications of installers

9. Warranty requirements, if desired

10. Quality control testing requirements

11. Fence and signage requirements, if required.

12. Field surveys and notes, soil investigations or geologic soil boring locations and soil classifications, earthwork or material estimates/quantities (if applicable);

13. Vegetative requirements; construction/installation criteria, State and Federal [OSHA] safety requirements, etc., type, quality and quantity as necessary;

14. Sufficient sectional, dimension or detail views of all system components and appurtenances (inlet and outlet pipes; method and details to protect liner including soil cover requirements; structural details, if required; drain and vent location and details; quality of materials; etc.) as required, for proper system functionality;

Use Arizona Construction and Material Specifications for each item of work and material, as applicable and available.

Additional specifications may need to be written to provide full material and installation instructions. Fill in blanks and add or delete items from the specifications to make them fit the job as needed.

Use Arizona standard drawings to the extent possible. These may be supplemented by additional drawings or specification notes on the drawings to provide full installation instructions.

The plans shall also address operations near existing utilities, trench excavations and any other items related to construction of the structure that may pose a safety risk to those involved.

All designs completed by non-NRCS personal shall meet minimum State licensing board requirements and NRCS requirements and criteria as outlined in the General Manual, the National Engineering Manual (including Arizona Supplements), and the National Engineering Handbook.

ONCE ALL PARTIES HAVE ACCEPTED AND SIGNED THE PLANS AND SPECIFICATIONS, NO CHANGES SHALL BE MADE TO THE DRAWINGS OR SPECIFICATIONS WITHOUT PRIOR APPROVAL OF NRCS.

OPERATION AND MAINTENANCE

A plan for operation and maintenance (O&M) of the liner and structure, *specific to*

each site, shall be prepared *and reviewed with the landowner, cooperator or individual responsible for operation and maintenance and shall be commensurate with the size and complexity of the project.* The plan shall be consistent with the purposes of the type of liner chosen, intended life, safety requirements and design criteria. *It shall document needed actions, including reference to periodic inspections and the prompt repair or replacement of damaged components, and should provide specific instructions for operating and maintaining facilities to ensure they function properly.*

The *O&M* plan shall contain requirements including, but not limited to:

1. Design capacity and liquid level of the structure.
2. A description of the normal operation, safety concerns and maintenance requirements.
3. Monitoring procedures for leak detection systems, including alarm level leakage rates and actions to be taken if these rates are exceeded.
4. Repair procedures.
5. Periodic inspection of the following:
   - Visible portions of the liner for tears punctures, or other damage;
   - Liner interface with inlets, outlets, ramps, or other appurtenances for damage;
   - Liquid level in the structure;
   - Ballooning of the liner indicating presence of gas beneath the liner.

6. Appurtenances such as trash racks, outlet structures, and valves shall be kept free of trash, debris, foreign materials or blockage and replaced when needed to prevent clogging of outlet and overflow pipes

7. Eradicate or otherwise remove all rodents or burrowing animals that have or may potentially damage any part of the delivery or application facilities. Immediately repair any damage caused by their activity.

8. The practice should be inspected periodically and especially after storm events to determine whether it is functioning properly or if repairs are needed.

9. Immediately repair any damage resulting from vandalism, vehicles, or livestock.

REFERENCES

ASTM D 5887-09, Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter

ASTM D 5890-06, Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners

ASTM D 5891-02(2009), Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners

ASTM D 5993-99(2009), Test Method for Measuring of Mass Per Unit of Geosynthetic Clay Liners.

ASTM D 6102-06, Guide for Installation of Geosynthetic Clay Liners.

ASTM D 6214-98(2008), Test Method for Determining the Integrity of Field Seams Used in Joining Geomembranes by Chemical Fusion Methods.

ASTM D 6392-08, Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

ASTM D 6497-02(2010), Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures.

ASTM D 7176-06, Specification for Non-Reinforced Polyvinyl Chloride (PVC) Geomembranes Used in Buried Applications.

ASTM D 7272-06, Test Method for Determining the Integrity of Seams Used in Joining Geomembranes by Pre-manufactured Taped Methods.

ASTM D 7408-08, Specification for Non Reinforced PVC (Polyvinyl Chloride) Geomembrane Seams.

ASTM D 7465-08, Specification for Ethylene Propylene Diene Terpolymer (EPDM) Sheet Used in Geomembrane Applications.

Koerner, R.M. 2005. Designing with Geosynthetics, 5th ed. Pearson Prentice Hall, Upper Saddle River, NJ.

Geosynthetic Research Institute, GRI Standard GC8, Standard Specification for Determination of the Allowable Flow Rate of a Drainage Geocomposite.

Geosynthetic Research Institute, GRI Test Method GT12(a) – ASTM Version, Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

Geosynthetic Research Institute, GRI Test Method GM13, Standard Specification for Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM17, Standard Specification for Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

Geosynthetic Research Institute, GRI Standard GM18, Standard Specification for Test Methods, Test Properties and Testing Frequencies for Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM19, Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM21, Standard Specification for Test Methods, Properties, and Frequencies for Ethylene Propylene Diene Terpolymer (EPDM) Nonreinforced and Scrim Reinforced Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM25, Standard Specification for Test Methods, Test Properties and Testing Frequency for Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes.

Giroud, J.P., and R. Bonaparte. 1989. Leakage through liners constructed with geomembranes—Part 1. Geomembrane Liners. *In* Geotextiles and Geomembranes, vol. 8, pgs. 27–67.

Quality Assurance and Quality Control for Waste Containment Facilities, EPA/600/R-93/182, September 1993.

- USDA-Natural Resources Conservation Service, National Engineering Handbook, Part 642, Specifications for Construction Contracts.