NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

IRRIGATION DITCH LINING

(Ft.)

CODE 428

I. DEFINITION

A lining of impervious material or chemical treatment, installed in an irrigation ditch, canal, or lateral.

II. PURPOSE

This practice may be applied as part of a resource management system to achieve one or more of the following purposes:

- Improve conveyance of irrigation water.
- Prevent water logging of land.
- Maintain water quality.
- Prevent erosion.
- Reduce water loss.

III. CONDITIONS WHERE PRACTICE APPLIES

This practice applies to constructed ditches that are subject to erosion or excessive seepage and are integral parts of an irrigation water distribution or conveyance system.

This practice applies where water supplies and irrigation deliveries for the area served are sufficient to make irrigation practical for the crops to be grown and the irrigation water application methods to be used.

This practice does not apply to natural streams.

IV. CRITERIA

Lined ditches shall be located where they are not susceptible to damage from side drainage flooding, or they shall be protected from such damage.

Provision shall be made to protect the lining from external water pressures, frost heave, chemical reactions with the soil and water, animal damage and fire when the lining is subject to damage from excess heat or fire.

Thickness of canal linings must be established on the basis of engineering considerations for each site. Location, canal size, velocity, subgrade conditions, method of construction, operation, lining material, and climate shall be evaluated in establishing thickness to be used.

A. Foundations

The foundation area for irrigation ditch lining shall be investigated, cleaned, shaped, smoothed, and firmed, prior to sealing.

Foundation investigations must be made to assure the following items can be addressed by the design:

1. Soil type and potential for seepage

2. Need for geotextile underlayment

3. Water table.

The extent of foundation investigations shall be based on the size and importance of the lining project. Investigation holes should be drilled on the downslope bank at a minimum of 500 foot intervals to adequately define foundation conditions.

B. Materials

On sites where sulfate, salts or other strong chemical concentrations exist and may cause damage to the lining, the lining material must be resistant to or otherwise protected from the chemicals most likely to damage the lining.

The required thickness for flexible membrane, chemical treatment, compacted clay, and semi-rigid formed plastic shall be

based on sub-grade conditions, the hydrostatic forces that will be acting on the lining and the susceptibility of the lining to damage during or after installation.

Table 1. — Minimum required thickness for flexible membrane, chemical treatment, compacted clay, and semi-rigid formed plastic linings

Material	Minimum thickness (mil unless noted)
PVC*	20
GCL*	0.75 lb/ft^2 sodium bentonite
EPDM	45
EPDM (reinforced)	45
Polyurethane/Geotextile composite	45
HDPE	30
LLDPE	20
PE (reinforced)	24
PP (reinforced)	24
Bituminous Geomembrane	120
Chemical Treatment	3 in
Compacted Clay	3 in

*Cover required (shall not be installed exposed)

Key: PVC – poly-vinyl chloride
GCL – geosynthetic clay liner
EPDM – ethelene propylene diene monomer (synthetic rubber)
HDPE – high-density polyethylene
LLDPE – linear low-density polyethylene
PE – polyethylene
PP – polypropylene

i. Concrete

Concrete linings installed under this standard shall be limited to ditches with:

- bottom widths not greater than 6 feet,
- flow capacities equal to or less than 100 cubic feet per second, and
- design velocities equal to or less than 15 feet per second.

Fly ash can be used to replace up to 15 percent of the cement by weight, when other pozzolans are not used. Fly ash material shall meet the requirements of ASTM C-618 "Standard Specification for Coal Fly Ash and Raw or Calcined Pozzalon for Use in Concrete".

Air-entrainment admixture is **required** to improve concrete workability and reduce damage due to freeze-thaw cycles. **In-place** air content shall be **in the range of 4 to 7** percent of the volume of concrete.

Concrete linings in soils with high sulfate concentrations shall be installed in accordance with those values shown in Table 2.

Table 2. Cement Requirements for Concrete Exposed to Sulfates

Water-soluble sulfate (SO_4) percent by weight	Sulfate (as SO_4) in water parts per million	Cement type ASTM C150 or C595
$SO_4 \geq 0$	$SO_4 \geq 0$	Any
$SO_4 \geq 0.10$	$SO_4 \geq 150$	II, IP(MS), IS(MS), P(MS), I(PM)(MS), I(SM)(MS)
$SO_4 \geq 0.2$	$SO_4 \geq 1500$	V
$SO_4 > 2.00$	$SO_4 \geq 10000$	V plus pozzolan*

*Pozzolan known or shown to improve sulfate resistance in concrete with Type V cement

Minimum thickness for plain concrete linings in rectangular sections shall be 3½ inches. For trapezoidal or parabolic sections, **the** minimum thickness shall be **3 inches for all designs**.

ii. Steel and Non-Ferrous Metal

Steel and non-ferrous metals subject to damage from soils or water with high salt or other chemical concentrations shall be protected with coatings, cathodic protection, or other methods specifically designed to protect the liner from these chemicals.

Galvanized lining material shall equal or exceed the requirements of ASTM A-525

"General Requirements for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process." The minimum thickness of the lining material shall be 24 gauge for individual sheets 84 inches or less in width, and 22 gauge for wider sheets. The minimum thickness of steel sheets used in bulkheads and related structures shall be 20 gauge.

The edges of the lining sheets shall be rolled or pressed into a shape that will provide added strength at the corners and a firm anchorage into the ditch bank berm at the top of the lining.

Fasteners and anchors used in the assembly of liners shall be zinc plated, cadmium plated, stainless steel or epoxy coated. Joints shall be flexible, watertight, and filled with sealant material capable of withstanding contraction/expansion of the lining material for the temperature variations expected at the site.

iii. Flexible Membrane and Semi-Rigid Formed Plastic

Flexible membrane and semi-rigid formed plastic linings, **unless permitted by the manufacturer to remain uncovered,** shall be protected from **exposure to the elements,** animal damage and from excessive heat or fire **to provide durability to the installation**.

iv. Chemical Treatment

Chemical treatment includes application of chemical compounds to the surfaces of earthen ditches and shall require incorporation and compaction of the combined soil/chemical mixture unless otherwise noted.

Table 3. — Minimum required application rate for finished compacted lining for chemical treatment of ditches

Material	Minimum application rate/compacted thickness $(lb/ft^2)/(in)$
TSPP*	0.0125
STPP*	0.0125
Soda Ash*	0.025
Bentonite*	See Soil Type
Silts	0.375
Silty Sands	0.5
Clean Sands	0.625
Soil Cement	1.25

* Cover required (shall not be installed exposed)

Key: TSPP – tetrasodium pyrophosphate
STPP – sodium tripolyphosphate
Soda Ash – sodium carbonate
Bentonite – sodium bentonite (min. free swell – 22 ml)
Soil Cement – mixture of Portland cement, soil and water

C. Subgrade Preparation

Flexible membrane lining material shall be placed on a relatively smooth, and firm surface **with sufficient slack accommodate thermal expansion and contraction (see Table 4). To achieve this, the subgrade surface shall be rolled with a smooth drum roller prior to liner placement.** The top 6 inches of the subgrade shall be free of organic material, **weed stocks, angular stones, or sharp particles greater than 3/8-inch for geo-membrane liners and ½-inch for geosynthetic clay liners** that could damage the lining. If the subgrade does not meet these criteria, a 6-inch layer of sand or soil, or an 8-ounce non-woven geotextile material, or a geomembrane composite, shall be used as padding beneath the lining.

Table 4. **Polyethylene Slack***

Sheet Temp	Min. Slack over 25 ft.	Min. Slack over 100 ft.
40º F	**1.5 in**	**6.0 in**
60º F	**2.0 in**	**8.5 in**
80º F	**2.5 in**	**10 in**
100º F	**2.5 in**	**12 in**
120º F	**3.0 in**	**13 in**
140º F	**3.3 in**	**14 in**
160º F	**3.6 in**	**16 in**
175º F	**4.0 in**	**17 in**

*** Note: Slack is determined using geomembrane temperature not air temperature. Solar heating has been shown to raise the temp of black lining material as much as 175º F on a clear hot day.**

D. Protective Cover

A protective soil or gravel cover for flexible membrane liners indicated in Table 4 shall be used. Cover soils shall not contain sharp, angular stones or any objects that could damage the liner. The material in the bottom 3 inches of cover shall **have a maximum allowable particle size of** 3/8-inch **for flexible membrane liners and ½-inch for geosynthetic clay liners, unless an 8-ounce or greater needle punched, non-woven geotextile material is placed between the liner and the cover soil. Successful covers often include sand and gravel for erosion protection.**

For flexible membrane liners protected by an earth or earth and gravel covering, the **required thickness** shall not be less than 6 inches thick and must extend not less than 6 inches above the top edge of the lining, unless recommended by the manufacturer to leave uncovered. **The minimum recommended cover depth is 10 inches plus 1 inch for each foot of water depth.** In areas subject to traffic by livestock, the minimum thickness of the protective cover shall be **16** inches and be free of particles larger than 3/8 inch, angular particles, and other sharp objects.

For HDPE and EPDM liners, side slopes may be exposed, however a minimum of 6-12 inches of soil cover shall be placed on the bottom of the canal section. Consider at least 12 inches of cover if placement or spreading is done with equipment in the bottom of the canal, or ditch cleaning will be part of the operation and maintenance plan.

Cover soils placed over membranes shall be evaluated for stability under saturated conditions that will occur when the canal is operating.

Any exposed manufactured lining material shall have sufficient ultraviolet protection to prevent premature deterioration.

Polyurethane/Geotextile composite linings may be exposed when installed according to manufacturer's recommendations.

For compacted clay or bentonite treatment liners, protection from the effects of desiccation or freeze thaw damage during periods when the ditch is empty is required. A protective soil or gravel cover of 6-12 inches shall be included. The soil cover shall be of a soil type, thickness, and density that is resistant to erosion and desiccation.

E. Cutoffs

Both covered **and exposed** liners require cutoffs **(perpendicular to flow) at each end of the lined section a minimum of 12 inches deep** and anchor trenches, **or horizontal runout anchors, both parallel to flow above the freeboard level** to secure the liner to the subgrade. **As a minimum, the manufacturer's recommendations shall be followed for all cutoff and anchor details.**

Exposed linings require **12-inch deep** cutoffs **placed no greater than 500 feet along the length of the lined section** and anchor trenches to secure the liner from **water flowing underneath causing** uplift or tearing away from the bottom and sides if the seams release **or tears develop.**

F. Seaming, Repairs, and Attachments

Attachments to concrete structures are not required; however in cases where they may be needed, attachments shall conform to manufacturer recommendations. Seaming and repairs of flexible liners shall conform to manufacturer recommendations.

G. Capacity

Lined ditches shall have adequate capacity to meet its requirement as part of the planned

irrigation water distribution or conveyance system, without damage or overtopping.

For design purposes, capacity shall be computed using Manning's formula based on maximum probable roughness condition with an "n" value not less than:

- Concrete – 0.015
- Steel/Non-Ferrous Metal – 0.013
- Flexible Membrane/SRFP* (covered) – 0.025
- Flexible Membrane/SRFP (exposed) – 0.011
- Chemical Treatment – 0.025

*** Semi-rigid formed plastic**

H. Velocity

In channels with non-covered concrete or metal linings, avoid unstable surge flows by limiting velocities to 1.7 times the critical velocity in straight reaches that discharge into ditch sections or structures designed to reduce the velocity to less than critical velocity. Maximum velocity in these straight reaches shall be 15 feet per second.

When using flexible membrane linings, follow the manufactures recommendations for velocity limitations.

In channels with covered linings, the stability of the cover material shall be evaluated by computing the velocity using a Manning's roughness coefficient "n" no greater than 0.025.

When soil material is used as a protective cover over a liner, the velocity in ditches shall not exceed the nonerosive velocity for the soil material or the material through which the canal or ditch passes, whichever is less. Local information on velocity limits for specific soils may be used if available. If such information is not available, stability limits shall be based on the tractive stress design approach in USDA - ARS (Agricultural Research Service) Agriculture Handbook Number 667 - "Stability Design of Grassed-Lined Open Channels," **USDA - SCS (NRCS) Technical Release 25, Chapter 6, Page 6-4, Figure 6-2, Allowable Velocities for Unprotected Earth Channels,** or other comparable channel stability criteria.

The velocity in ditch reaches from which water is to be delivered onto the field through gates, turnouts, siphon tubes or by similar means, shall be less than supercritical and sufficiently low to permit operation of the planned structure or device.

I. Freeboard

The required freeboard varies according to the ditch, velocity of water, horizontal and vertical alignment, the amount of storm or wastewater that may be intercepted, and the change in water surface elevation that may occur when any control structure is operating. The minimum freeboard for any lined ditch or canal shall be 3 inches of lining above **both sides of** the design water surface. If the design velocity is within ± 30 percent of critical velocity, the freeboard shall be at least 6 inches.

Minimum freeboard requirement is based on assumption that the finished channel bottom elevation will vary no more than 0.1 feet from design elevations. If a construction deviation greater than 0.1 feet is permitted, the minimum freeboard shall be increased.

Additional freeboard shall be provided if required by velocity, depth of flow, alignment, obstruction, curves, and other site conditions.

J. Water surface elevations

All lined ditches shall be designed so that water surface elevations at field takeout points are high enough to provide the required flow onto the field surface. If ditch checks or other control structures are to be used to provide necessary head, backwater effect must be considered in computing freeboard requirements.

The required elevation of the water surface above the field surface varies with the type of takeout structure or device used and the amounts of water to be delivered. A minimum head of 4 inches shall be provided. Where erosion is anticipated at outlets, energy dissipation devices shall be used.

K. Ditch side slopes

For the construction methods and materials shown below, side slopes shall not be steeper than:

Hand-placed, formed concrete:
Height of lining less than 1½ ft .....Vertical

Hand-placed, screeded concrete:
Height of lining less than 2½ ft ....3/4H to 1V*
Height of lining more than 2½ ft .....1H to 1V

Slip form concrete:
Height of lining less than 3 ft .....1H to 1V
Height of lining more than 3 ft ....1¼H to 1V

Chemical Treatment:
Spray/stair-step applications .....1H to 1V
Incorporation on slope .... 3H to 1V

Covered lining:
Not less than ..... 3H to 1V

Exposed lining:
Not less than ..... 1.5H to 1V

*H – Horizontal, V – Vertical

For materials not listed above, follow the manufacturer's recommendations.

L. Ditch banks

Ditch banks shall be shaped with earth to at least the top edge of the lining and to provide any necessary anchorage for the top edge of the lining. In cut sections, other than in rock, a berm shall be constructed not less than 2 inches above the top of the lining. Banks and berms shall be a wide enough to ensure stability of fills, the lining, and to prevent excessive deposition in cut sections.

When using siphon tubes, minimum berm or bank width of 12 inches shall be provided at the top of the lining on both sides of the finished ditch. All other canals and laterals shall have a minimum berm or bank width of 18 inches at the top of lining.

If the bank or berm is to be used as a roadway, the minimum top width shall be adequate for the purpose. Minimum recommended roadway width for straight sections is 12 feet.

Outside bank slopes and slopes above the berm elevation in cut sections must be flat enough to insure stability. A minimum slope is 2H to 1V is recommended. Where vegetation will be maintained by mowing, the minimum slope shall be 3H to 1V.

M. Related structures

Plans for ditch lining installations shall provide for adequate inlets, outlets, turnouts, checks, crossings, and other related structures needed for the successful management of irrigation water.

Structures shall be constructed or installed such that the capacity or the freeboard of the ditch is not reduced and the effectiveness of the lining is not impaired.

Bulkheads, formed to fit the lining and of sufficient size to extend at least 12 inches into the earthen ditch pad for the entire width of the ditch lining, shall be installed at the beginning and end of the lining section and at intervening points, as needed, to provide adequate anchorage.

N. Vegetation

Disturbed areas not otherwise covered or protected, shall be established as soon as practicable after construction is completed.

V. CONSIDERATIONS

- **Consider livestock or animal crossing locations to include 3:1 side slopes or flatter with a minimum 16-inch of sand and gravel material, or concrete**
- The addition of fiber reinforcement to increase durability and reduce the potential for minor cracking in concrete
- Effects of downstream flows or aquifers that would affect other water uses or users
- Potential changes in growth and transpiration of vegetation located next to the conveyance because of elimination of leakage from the system
- Effects on the movement of dissolved substances into the groundwater
- Effects on wetlands or water-related wildlife habitats
- Effects on the visual quality of water resources

- Energy savings resulting from less water loss and improved irrigation water management
- Short-term and construction-related effects on air quality

VI. PLANS AND SPECIFICATIONS

Plans and specifications for installing irrigation ditch and canal linings shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

At as minimum plans should include: plan view, profile, and installation details.

VII. OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan shall be developed for irrigation ditch and canal linings. The plan should document needed actions to ensure that practices perform adequately throughout their expected life.

O&M requirements shall be determined as part of the design. Any requirements should be documented as brief statements in the plans, the specifications, or the conservation plan narrative, or as a separate O&M plan. Typical O&M may include sediment/debris removal, patching of cracked concrete, and replacement of deteriorated linings.

VIII. REFERENCES

Performance of Plastic Canal Linings, REC-ERC-84-1, U.S. Dept. of the Interior, Bureau of Reclamation.

Use of Geomembranes in Bureau of Reclamation Canals, Reservoirs, and Dam Rehabilitation, REC-95-01, U.S. Dept. of the Interior, Bureau of Reclamation.

Layfield Group, Specifications, Template-Geomembrane Slack.