



Natural Resources Conservation Service
CONSERVATION PRACTICE STANDARD
IRRIGATION SYSTEM, SURFACE AND SUBSURFACE

Code 443

(Ac)

DEFINITION

A system in which all necessary earthwork, multioutlet pipelines, and water-control structures are installed for distribution of water by surface means, such as furrows, borders, and contour levees, or by subsurface means through water table control.

PURPOSE

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

- Efficiently convey and distribute irrigation water to the soil surface point of application without causing excessive water loss, erosion, or water quality impairment.
- Efficiently convey and distribute irrigation water to the subsurface point of application without causing excessive water loss or water quality impairment.
- Apply chemicals and/or nutrients as part of a surface irrigation system in a manner which protects water quality.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

Areas must be suitable for irrigation and water supply must be adequate in quantity and quality to make irrigation practical for planned crops to be grown and application methods to be used.

This standard does not apply to detailed design criteria and construction specifications for individual water control or conveyance structures, or appurtenances.

Surface irrigation site conditions will enable target application efficiency and distribution uniformity to be achieved.

Site conditions for a subsurface irrigation system shall be such that a water table can be created and maintained to supply water to the crop root zone.

Subsurface irrigation under this standard applies to irrigation through water table control by adding water at water control structures and using perforated pipe, tubing (usually 3-inches-or-greater diameter), or ditch structures to raise the water table.

This standard does not apply to irrigation systems employing subsurface line-source emitters on buried drip tapes or tubing which is addressed with Conservation Practice Standard (CPS), Irrigation System, Microirrigation (Code 441).

NRCS reviews and periodically updates conservation practice standards. To obtain the current version of this standard, contact your Natural Resources Conservation Service [State office](#) or visit the [Field Office Technical Guide](#).
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CRITERIA

General Criteria Applicable to All Purposes

Conservation irrigation methods. Design the irrigation system as an integral part of an overall plan of conservation land use and treatment for the farm that is based on capabilities of the land and needs of the irrigated area.

Base the farm irrigation system design on sound irrigation water application methods which are suited to site conditions (combination of soil and slope) and crops to be grown. Adapted methods are those methods that provide efficient use of water without destructive soil erosion or water quality degradation.

Capacity. The irrigation system must have adequate capacity to meet the intended purpose(s). If more than one irrigation method will be used on the same field, the system capacity must be adequate for the method requiring the highest water delivery rate.

Design all structures and water delivery components for maximum flow conditions expected and adequate capacity and freeboard.

Water control. Farm irrigation systems must include necessary structures required for water regulation and control such as: measuring devices, division boxes, checks, turnouts, pipelines, lined ditches, valves, pumps, and gates.

Additional Criteria Applicable to Surface Irrigation Systems

Design of physical components shall be in accordance with CPSs Irrigation Pipeline (Code 430); Irrigation Canal or Lateral (Code 320); Irrigation Field Ditch (Code 388); Structure for Water Control (Code 587); Pumping Plant (Code 533); Irrigation Land Leveling (Code 464); Irrigation System, Tailwater Recovery (Code 447), and other pertinent CPSs.

Application Efficiency and Distribution Uniformity. Use local irrigation guides or NRCS National Engineering Handbook (NEH) Part 623, Chapter 4, to select the appropriate surface irrigation method and combination of field slope, length, configuration, flow rate, and tailwater management to achieve target or design application efficiencies (AE) and distribution uniformity (DU) values.

Capacity. In computing capacity requirements, allowance must be made for reasonable water losses during application and any leaching requirements.

Design application rate. The design rate of application must be within a range established by the minimum practical application rate for climatic conditions and the maximum rate consistent with the soil water intake rate and conservation practices used on the land.

Water surface elevation. Design all systems for irrigation by surface methods with a water surface elevation at field takeout points adequate to provide required flow onto the field surface. Provide at least 4 inches of head .

Location of delivery ditches or aboveground, multioutlet distribution pipelines. Locate delivery ditches or pipelines used for surface irrigation so irrigation water can be applied uniformly over the entire field without causing erosion. Space the ditch or pipeline such that irrigation run lengths are not longer than maximums specified in local irrigation guides or those determined acceptable based on field slopes. If more than one crop is to be grown or more than one method of irrigation used, the ditch or distribution pipeline spacing must not exceed the allowable run length determined for the limiting crop or method.

Irrigation Water Management. Develop an irrigation water management plan meeting requirements of CPS Irrigation Water Management (Code 449) for use with this practice.

Aboveground, multi-outlet distribution pipeline.

Working pressure. The maximum working pressure for all aboveground, multi-outlet distribution pipe except for poly irrigation tubing will be 10 pounds per square inch or 23 feet of head. Install appropriate head control appurtenances to reduce maximum working pressure to acceptable levels.

For poly irrigation tubing, follow the manufacturer's recommendations for maximum allowable working pressure. If the manufacturer's recommendations are not available, use the hoop stress formula in NRCS National Engineering Handbook (NEH) Part 636, Chapter 52 to determine maximum working pressure, with a factor of safety of 1.5.

Friction losses. For design purposes, friction head losses must be no less than those computed by the Hazen-Williams equation, using roughness coefficients of $C=130$ for aluminum pipe and $C=150$ for plastic or poly irrigation tubing.

Flow velocity. When operating at system capacity, the velocity in the pipeline will not exceed 7 feet per second unless appropriate surge protection is provided.

Capacity. The design capacity of the pipeline will be sufficient to deliver an adequate irrigation stream to the design area for the planned irrigation method.

Outlet gates. Individual outlet gates will have the capacity at design working pressure to deliver required flow to a point at least 4 inches above the field surface.

Head requirement. The working head will not be less than 0.5 foot above outlet gates, unless a detailed design or manufacturer's literature indicates a lower head is adequate to deliver required water to the field.

Where either design working head exceeds 5 feet or stream flows are erosive, install an effective method of energy dissipation at each gate, or establish and maintain permanent vegetation along the pipeline to provide erosion control.

Flushing. A suitable outlet shall be installed at the end of the pipeline for flushing the line free of sediment or other foreign material.

Materials. Select aluminum or plastic pipe material certified for above-ground use. All fittings and couplers must have a pressure rating that exceeds or is equal to the pressure rating of the pipe. They must be made of material recommended by the manufacturer as compatible for use with the pipe.

Furnish the pipe and appurtenances with a coupling system which is compatible with the selected pipe material.

Select rubber gaskets according to the manufacturer's standard design dimensions and tolerances for the pipe material selected. Each gasket must be of such size and shape that, after assembly, adequate compressive force is provided against the spigot and socket to affect a positive seal. The gasket must be a continuous elastomeric ring and will be the sole element depended upon to make the joint flexible and watertight.

Minimum wall thickness for aluminum gated pipe will be 0.050 inches for 6 through 10 inches in diameter, and 0.058 inches for 12-inch diameter pipe.

Corrosion protection shall be provided for aluminum pipe when—

- Conveying water with a copper content exceeding 0.02 parts per million.
- In contact with soil having a resistivity of less than 500 ohm-centimeters.
- In contact with soil having a pH less than 4 or greater than 9.

Minimum wall thickness of PVC gated pipe including consideration of any standard manufacturing tolerances must be not be less than 0.09 inch. The pressure rating of the pipe shall be 22 pounds per square inch or greater, prior to gate installation.

Minimum wall thickness of poly irrigation tubing will be 6 mil (0.006 inch).

Related structures. An open ditch supply will include a permanent water control structure as the inlet to multioutlet pipe.

When the water supply for poly irrigation tubing is greater than 0.5 foot above the ground, use a PVC or aluminum fitting to convey water between the supply outlet and the poly irrigation tubing at ground level.

Erosion control. Design the farm irrigation systems to convey and distribute irrigation water without causing damaging soil erosion. Provide nonerosive gradients on all unlined ditches. If water is conveyed on slopes steep enough to cause excessive flow velocities, install structural erosion control measures such as pipe drops, chutes, buried pipelines, and erosion-resistant ditch linings. Polyacrylamide may be applied for erosion control according to CPS Anionic Polyacrylamide (PAM) Application (Code 450) in lieu of, or in combination with structural measures.

Seepage control. If site conditions require conveyance of water across excessively permeable soils, provide the irrigation system design shall provide for pipelines, flumes, or lined ditches, as needed, to prevent excessive seepage losses.

Tailwater and excess runoff removal. Include facilities of adequate capacity for safe removal of irrigation tailwater and storm water runoff. If erosion is a hazard, collection facilities (ditches) constructed for this purpose will be on nonerosive gradients or stabilized by lining or structural measures. If field elevations do not permit nonerosive disposal of tailwater or excess water by gravity flow, shall provide for installation of pumping plants and other needed appurtenant structures. Protect from bank erosion.

If excess water will be reused for irrigation, include a tailwater reuse system that conforms to CPS Irrigation System, Tailwater Recovery (Code 447).

Additional Criteria Applicable to Subsurface Irrigation Systems

Design subsurface irrigation systems to maintain the water table at predetermined design elevations below the ground surface at all points in the application area.

Space feeder ditches or conduits for subsurface irrigation so the variation in depth from the land surface to the water table provides adequate irrigation of the most limiting crop to be grown.

Design of physical components must be in accordance with CPSs Subsurface Drain (Code 606), Structure for Water Control (Code 587), Pumping Plant (Code 533), and other pertinent CPSs.

Soils. Site conditions must be such that water can move laterally from open ditches or irrigation tiles to form and maintain a water table at the design depth as specified in the irrigation water management plan. Do not use subsurface irrigation unless the irrigated area has a slowly permeable water restrictive layer.

Soil survey information for the irrigated area can be used in preliminary planning. Final design shall be based on onsite lateral hydraulic conductivity measurements or average lateral hydraulic conductivity determined from laboratory tests of each soil layer.

Lateral Spacing. Space laterals equally in each subunit. Maximum spacing of irrigation tiles or open ditches will be no more than one-half the lateral or ditch spacing specified in local drainage guides, or no more than one-half the lateral or ditch spacing computed using procedures found in NRCS NEH, Part 650, Chapter 14; or NRCS NEH, Part 624.

Water Control. Within each managed subunit, provide a water level control structure of sufficient size to allow adequate flow to meet water requirements of that subunit. The control structures should be set on elevation intervals not to exceed 1 foot.

Water level control structures must be covered or otherwise protected to prevent accidental entry by animals, livestock, machinery, or humans.

Irrigation Water Management. Develop an irrigation water management plan meeting requirements of CPS Irrigation Water Management (Code 449) for use with this practice.

Additional Criteria Applicable to Application of Chemicals and/or Nutrients with a Surface Irrigation System

The installation and operation of an irrigation system for the purpose of chemical and/or nutrient application must comply with all applicable Federal, State and local laws, rules and regulations. This includes backflow and antisiphon prevention measures to protect surface water and groundwater sources. Additionally, protect surface waters from direct application and runoff.

Design of physical components shall be in accordance with CPSs Irrigation Pipeline (Code 430), Waste Transfer (Code 634), Structure for Water Control (Code 587), Pumping Plant (Code 533), and other pertinent CPSs.

Capacity. Ensure the design capacity is adequate to supply the specified amount of chemical and/or nutrients to the design area in the specified operating period.

Nutrient and Pest Management. Apply chemicals, fertilizers, waste water, and liquid manure in accordance with appropriate CPSs Nutrient Management (Code 590), Integrated Pest Management (Code 595), or Waste Utilization (Code 633).

Additional Criteria Applicable to Reduce Energy Use

Provide analysis to demonstrate reduction of energy use from practice implementation.

Calculate the reduction of energy use as an average annual or seasonal energy reduction compared to previous operating conditions.

CONSIDERATIONS

When planning this practice consider the following items:

- Effects of soluble salts, nutrients, and /or pesticides on surface water and groundwater quality.
- Effects of saturated water levels on such soil nutrient processes as plant nitrogen use or denitrification, and root development.
- Effects on the soil biota which will alter nutrient cycling carbon utilization. Water-logged and tillage-dominated soils become bacteria-driven systems which denitrify and ineffectively utilize carbon.
- Effects on aquatic and wildlife communities, wetlands, or water-related wildlife habitats, including effects upon pollinator foraging and nesting habitats.
- When planning and designing surface and subsurface irrigation systems: soil texture, intake, slope, and depth are important soil properties which influence installation, performance and soil limitations related to intake rate, seepage, corrosivity, and soil compaction. Designers should refer to soil survey information for the irrigated area during preliminary planning and conduct on-site soil investigations prior to final design.

When designing a surface irrigation system the following should be considered:

- To improve surface irrigation efficiency surface tillage should be reduced when possible. The destruction of soil structure caused by physical and chemical disturbance can severely impede some soils ability to take in water.

- Impact of salt leaching requirements on system management, capacity, and drainage requirements.
- Effects of erosion and/or movement of sediment and sediment-attached substances carried by runoff including salinity, nutrients, pesticides, seeds, and vegetative portions of invasive plants.
- Effect of elevated irrigation tailwater temperatures on downstream receiving waters.
- Irrigation system capacity should be determined based on appropriate design application efficiency. Design application efficiency should be no greater than 90 percent for properly designed level surface irrigation systems and a maximum of 80 percent for graded systems. Guidance for selecting design application efficiencies is provided in NRCS NEH Parts 623 and 652.
- Design, evaluation, and simulation models WinSRFR can be very useful tools in finalizing surface system designs.

When designing a subsurface irrigation system the following should be considered:

- Potential benefits of water level control on downstream water quality.
- Potential effects of practice management on lateral seepage.
- Orienting lateral lines along the contours to maximize the area influenced by each water level control structure.
- Soil layers in the water transmission zone (root zone) should have a higher lateral saturated hydraulic conductivity than the vertical saturated hydraulic conductivity of the water restrictive layer. However, if lateral hydraulic conductivity of any single soil layer in the root zone exceeds 10 times that of other layers, lateral seepage may make it difficult to raise the water table to the design depth.
- Irrigation system capacity should be determined based on an appropriate design application efficiency. Design application efficiency should be no greater than 90 percent for soils with minimal lateral losses and a maximum of 75 percent for all other soils.
- Be aware that additional pumping capacity may be needed to raise the water table during drought periods.
- Design procedures and guidance for subsurface irrigation system planning and design are provided in NRCS NEH Part 624, Chapter 10.

When planning a surface irrigation system employing an above ground, multioutlet, distribution pipeline the following should be considered:

- Provisions should be made for thrust control at locations subject to pipe movement.
- Good grade control along the pipeline and along the rows is needed to assure uniform water distribution.
- Consider the water source and potential trash types and amounts when designing or selecting inlet screen types and sizes.
- Plan for disposal of used poly irrigation tubing and encourage recycling.
- Anchor poly irrigation tubing when winds may cause it to move.
- PVC gated pipe with wall thickness less than 0.12 inch will be more flexible making soil support and uniform pipe grade more important if an irrigation stream contains sand. Sand will tend to settle and accumulate in any gated pipe lows.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for surface and subsurface irrigation systems shall be in keeping with this standard and that describe the requirements for applying this practice to achieve its intended purpose.

- Soils investigation
- Crop needs
- Survey data: profile and topography
- Design computations
- Plan view of site with existing and planned features, including distances, dimensions, etc.
- Materials and quantities needed
- Practice specifications

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan specific to the facilities installed for use by the landowner or operator responsible for operation and maintenance. The plan should provide specific instructions for operating and maintaining facilities to ensure they function properly. At a minimum, address—

- Periodic cleaning and regrading of tailwater collection facilities to maintain proper drainage, capacity, and functionality.
- Periodic checks and removal of debris as necessary from trash racks and structures to ensure proper operation.
- Periodic removal and planned placement of sediment from traps and/or storage facilities to maintain design capacity and efficiency.
- Inspection and testing of all pipeline and pumping plant components and appurtenances.
- Routine maintenance of all mechanical components in accordance with the manufacturer's recommendations.
- Periodic land smoothing or grading of surface irrigated fields required to maintain the design grade in the direction of flow.

Additionally for a subsurface irrigation, the plan will include, as a minimum—

- Water control structure elevation settings by date required to maintain water table at design depth.
- Critical dates and water table target elevations during planned crop growing season.
- Inclusion of specification and locations of all required groundwater observation wells.

REFERENCES

USDA-NRCS, National Engineering Handbook (NEH), Part 623, Irrigation, Chapter 4, Surface Irrigation.

USDA-NRCS, NEH, Part 624, Drainage, Chapter 10, Water Table Control.

USDA-NRCS, NEH, Part 636, Chapter 52, Structural Design of Flexible Conduits.

USDA-NRCS, NEH, Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage).

USDA-NRCS, NEH, Part 652, National Irrigation Guide.