NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

SPRINKLER SYSTEM

(Acre)

CODE 442

DEFINITION

A distribution system that applies water by means of nozzles operated under pressure.

PURPOSE

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

- Efficiently and uniformly apply water on irrigated lands.
- Improve plant condition, productivity, health and vigor.
- Prevent the entry of excessive nutrients, organics, and other chemicals in surface and groundwater.
- Improve condition of soil contaminated with salts and other chemicals.
- Reduce particulate matter emissions to improve air quality.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to the planning and functional design of all sprinkler system components such as laterals, risers, nozzles, heads, and pressure regulators.

Individual sprinkler design discharge rates covered by this standard typically have design nozzle discharge rates exceeding 1 gallon per minute.

Areas must be suitable for sprinkler water application and have a water supply of adequate quantity and quality suitable for the intended purpose(s).

This standard applies to planning and design of sprinkler application systems for the following:

- Meeting crop water demands.
- Accomplishing crop cooling, frost protection, or bloom delay.
- Leaching or reclaiming saline or sodic soils or soils contaminated by other chemicals that can be controlled by leaching.
- Applying chemicals, nutrients, and/or wastewater.
- Controlling dust and particulate from confined animal pen areas, unpaved roads, staging areas, and equipment storage yards.

This standard applies to renozzling existing sprinkler systems to reduce pressure, reduce flow rate, or increase distribution uniformity.

This standard does not include criteria for mini- or micro-sprinkler systems. These are covered by Conservation Practice Standard (CPS) 441, Irrigation System, Microirrigation.

CRITERIA

General Criteria Applicable to All Purposes

The criteria for the design of components not addressed in conservation practice standards shall be consistent with sound engineering principles.

Each sprinkler system must be an integral part of a conservation plan that addresses intended purpose(s) and operator needs. Base system selection on site evaluation, operating conditions, soils, and topography.

Design sprinkler positions, flow rates, and operating pressures within manufacturers' recommended ranges.

System Capacity. Sprinkler capacity must be adequate to accomplish the primary purpose(s) of the system. Determine capacity based on appropriate design application efficiency. Select design application efficiency based on system type and purpose.

In computing capacity requirements, allowance must be provided for reasonable application water losses, system maintenance downtime, and auxiliary water requirements such as leaching. Using 23 hours per day for daily irrigation duration will help to ensure capacity. For full irrigation, use 80% chance rainfall and for limited irrigation use 50% chance rainfall unless documentation allows another basis.

Pipelines. The design of main lines, submains, and supply lines shall ensure that required water quantities can be conveyed to all operating lateral lines at required pressures. For detailed criteria, see CPS 430, Irrigation Pipeline.

Pump and power unit. Where required, pump and power units shall be adequate to efficiently operate the sprinkler system at design capacity and total dynamic head. For detailed criteria, see CPS 533, Pumping Plant.

Criteria Applicable to Efficient and Uniform Application of Water on Irrigated Lands

Design application rate and depth. Select application rates and depths that will minimize runoff, translocation of water or soil, and deep percolation (except for planned leaching).

Design maximum application rate to be consistent with soil intake rate, slope, and conservation practices used on the land. If sprinkler design application rate exceeds soil infiltration rates, use boom backs or additional storage features such as furrow dikes and enhanced residue management to minimize runoff. In lieu of approved runoff model simulation results (for example, CPNozzle), use field observations to assess the need for runoff prevention measures.

Distribution patterns, nozzle spacing, and height. Select a combination of sprinkler spacings, nozzle sizes, and operating pressures that provide the design application rate and a uniform distribution.

Use Coefficient of Uniformity (CU) data or Distribution Uniformity (DU) as defined in Chapter 11 in National Engineering Handbook Section 15 (NEH 15), *Irrigation*, or in Chapter 6 in National Engineering Handbook Part 652 (NEH 652), *Irrigation Guide*, when selecting sprinkler spacing, nozzle size, and operating pressure.

Overall projected system runoff (water translocation) shall average less than 1 percent. Sprinkler wetted diameters will be as published by the manufacturer's performance tables. Sprinklers that operate in the crop canopy most of the time shall be evaluated based upon a reduced wetted diameter as compared to the non-canopy wetted diameter. The row grade should be used to calculate runoff rather than land slope when all furrows across the land slope are high enough to direct runoff water.

Design capacity. For the purpose of crop irrigation, sprinkler irrigation systems shall have either (1) a design capacity adequate to meet peak water demands of all irrigated crops in the design area or (2) an adequate capacity to meet requirements of selected irrigations during critical crop growth periods when less-than-full irrigation is planned (Section KS652.0408 in NEH 652).

Management plan. An irrigation water management plan that meets CPS 449, Irrigation Water Management, shall be developed.

Center pivot and linear move systems. Center pivot and linear move systems can have various sprinkler styles and placement. Definitions of these systems are located in Section KS652.0605(c) in NEH 652. For center pivot and linear move systems, select sprinkler spacing, nozzle height, and operating pressure to provide required CU. For center pivots, compute CU using the Heermann-Hein weighted area method. For linear systems, compute CU using equivalent unit areas (Christensen method). The minimum CU value for a pivot or linear move system is 90% (84% DU). If the manufacturer-provided CU information is not available, use Center Pivot Evaluation and Design (CPED) software or other modeling software that is approved by the Natural Resources Conservation Service (NRCS) to estimate CU values.

For center pivot and linear move systems with nozzles that operate in the canopy for 50% or more of the growing season, nozzle spacing shall not exceed every other crop row or 80 inches maximum. In-canopy heights shall be such that areas of high leaf concentration are avoided (for example, avoid sprinkler height in corn near ear height—approximately 4 feet). Use nozzle heights higher or lower than high leaf concentration areas. In-canopy operation should not be practiced on narrow and ultra-narrow row plantings.

For all other center pivot and linear move systems, the following nozzle spacing criteria apply. From a point midway between the first and second tower to the distal end of center pivots and for the entire length of linear move systems, nozzle spacing along lateral lines shall not exceed 25% of wetted diameter for fixed position spray sprinklers, 40% for rotating or oscillating sprinklers, and 50% for impact sprinklers. Base the wetted diameter on manufacturer's information for the design nozzle height and pressure. Limit nozzle spacing and pressures to within the manufacturer's recommended ranges.

Low energy precision application (LEPA). LEPA systems shall discharge water between alternate crop rows. LEPA nozzle spacing shall not exceed 80 inches. Water shall discharge through a sock or hose dragged on the ground or through a nozzle with a bubble shield or pad set at a uniform height of 18 inches or less.

LEPA systems are only applicable on crops planted with furrows or beds. LEPA systems shall have row patterns that match the lateral line movement (such as circular for center pivots or straight row for linear move). Tower wheel tracks shall not be irrigated. Runoff and water translocation under LEPA systems shall be eliminated by providing surface basin storage such as furrow dikes, dammer dikes, or implanted reservoirs.

Fixed-solid set, big gun, periodic move, and traveling sprinkler systems. For these systems, CU (or DU) data shall be used when selecting sprinkler spacing, nozzle size, and operating pressure. CU shall not be less than 75% (60% DU) for deep-rooted (4 feet or more) field and forage crops where fertilizers and pesticides are not applied through the system. CU shall not be less than 85% (76% DU) for high-value or shallow-rooted crops and for any crop where fertilizer or pesticides are applied through the system. Tables 1a and 1b provide maximum sprinkler and lateral spacings for fixed-solid set, big gun, and periodic move systems with rectangular and triangular layout patterns.

For traveling sprinkler irrigation systems, use Table 2 for towpath spacing.

Land slope. Field slope for a LEPA system shall not exceed 1% on more than 50% of the field with a maximum slope of 3%.

Field slopes for center pivot or linear move systems with sprinklers on drops shall not exceed 3% on more than 50% of the field for fine and moderately fine soils as described in Table 2-5 in NEH 652. On coarser soils, center pivot or linear move systems installed on slopes greater than 5% are required to have a runoff analysis detailing how runoff will be controlled. This analysis shall be based on field observations or approved runoff models (for example, CPNozzle).

Regardless of soil texture for center pivot or linear move systems that operate sprinklers within the crop canopy for 50% or more of the growing season, field slopes shall not exceed 3% on more than 50% of the field.

Maximum field slopes for center pivot or linear move systems shall not exceed manufacturer's slope limitations based on pivot profile, span length, pipe diameter, and tire size.

Table 1a–Maximum spacing for fixed-solid set, big gun, and periodic move sprinklers with rectangular pattern

Sprinkler Classification (Operating Pressure in pounds per square inch)	Average Wind Velocity (miles per hour [mph])	Lateral Spacing (percent)*	Sprinkler Spacing (percent)*
Low (2-35 psi) Moderate (35-50 psi) Medium (50-75 psi)	0 to 1	65	50
	1 to 5	60	50
	5 to 10	50	50
	> 10	45	50
		Maximum Diagonal Distance Between Sprinkler Locations on Adjacent Laterals (percent)*	
High (> 75 psi)	0 to 4	65	
	4 to 10	50	
	> 10	30	
* Percent of wetted diameter when operating at design pressure is based on manufacturer's performance tables.			

Table 1b–Maximum spacing for fixed-solid set, big gun, and periodic move sprinklers with triangular pattern

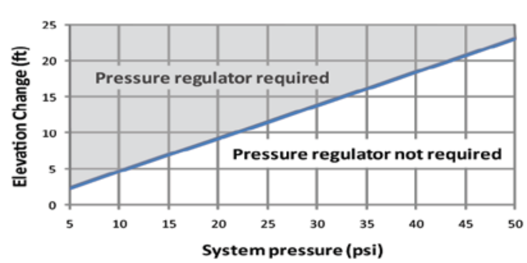
Sprinkler Classification (Operating Pressure in psi)	Average Wind Velocity (mph)	Lateral Spacing (percent)*	Sprinkler Spacing (percent)*
Low (2-35 psi) Moderate (35-50 psi) Medium (50-75 psi)	0 to 1	70	65
	1 to 5	65	65
	5 to 10	54	65
	> 10	48	65
* Percent of wetted diameter when operating at design pressure is based on manufacturer's performance tables.			

Table 2–Towpath spacing for traveling sprinkler systems (expressed as percent of wetted diameter*)

Average Wind Velocity (mph)	Ring Nozzle	Tapered Nozzle
0 to 1	80	80
1 to 6	70	75
6 to 10	60	65
> 10 **	50	55
* Percent of wetted diameter when operating at design pressure is based on manufacturer's performance tables. **Because the distribution pattern of traveling systems is seriously affected by wind, operation in winds greater than 10 mph is not recommended.		

Pressure regulators. Pressure regulators are required on center pivot and linear move sprinkler outlets if pressure variation at any sprinkler (resulting from elevation difference) exceeds 20% of the design operating pressure at that sprinkler (Figure 1).

Figure 1–Elevation change that requires pressure regulators



Elevation changes in the field have the largest impact on operating pressures. (For example, a sprinkler operating at 20 psi in a field with a 9.2-foot elevation difference can have a 20 percent or 4 psi change in pressure.) Without regulators, operating pressure and pumping cost usually will not increase significantly if the elevation does not change much from the pivot point to the end of the lateral. Where elevation changes are great, the choice is to increase operating pressure (and probably pumping cost) or to use pressure regulators. This decision is site-specific and should be made by comparing the extra cost of pressure regulators to the increased pumping cost without them.

Documentation shall include enough survey information to verify the elevation changes in the field.

In the absence of the manufacturer's recommendations, line pressure immediately upstream of the pressure regulator shall be at least 5 psi above the rated pressure.

Lateral lines. Unless pressure reducers or regulators are installed at each outlet or other pressure-compensating or flow control devices are used, lateral lines shall be designed so that pressure variation along the lateral line does not exceed 20% (or 10% of design flow) of the average design operating pressure.

Risers. Except for under-tree operation, riser pipes used on lateral lines shall be high enough to prevent interference with the distribution pattern when the tallest crop is irrigated. Riser heights shall not be less than shown in Table 3.

Table 3–Riser heights

Sprinkler Discharge (gallons/minute)	Riser Height* (inches)
Less than 10	6
10-25	9
25-50	12
50-120	18
More than 120	36

* Risers over 3 feet in height shall be anchored and stabilized.

Additional Criteria Applicable to Improve Plant Condition, Productivity, Health, and Vigor

Design capacity. As a minimum, use peak daily evapotranspiration for design capacity on sprinkler systems used for soil cooling.

Sprinkler systems used for foliar cooling shall have sufficient capacity to satisfy the crop's evaporative demand on a minute-by-minute basis throughout peak use hours during peak use days. Chapter 2 in National Engineering Handbook Part 623 (NEH 623), *Irrigation*, contains guidance on using sprinkler irrigation systems for temperature control.

The design capacity for systems used for cooling or frost protection shall be adequate to allow water application to the entire area simultaneously.

Design application rate. For frost protection, base the application rate on minimum air temperature, maximum anticipated wind speed, and relative humidity. The sprinkler system shall uniformly apply water at the design application rate over the entire area simultaneously. Chapter 2 in NEH 623 contains guidance on using sprinkler irrigation systems for frost protection.

Additional Criteria Applicable to Prevent the Entry of Excessive Nutrients, Organics, and Other Chemicals in Surface and Groundwater

Comply with all federal, state, and local laws, rules, and regulations regarding backflow and anti-siphon prevention measures on the installation and operation of a sprinkler system designed for the purpose of chemical, nutrient, or wastewater application. Chemicals, fertilizers, and liquid manure shall be applied in accordance with appropriate NRCS conservation practice standards. Surface waters shall also be protected from direct chemical, nutrient, or wastewater applications. Variable rate irrigation can be used to prevent the application of chemicals or wastewater to surface waters and their associated buffer areas.

Chapter 2 in NEH 623 contains guidance on using sprinkler irrigation systems for chemigation.

Injectors (for chemical, fertilizer, or pesticide) and other automatically operating equipment shall be located adjacent to the pump and power unit and installed in accordance with state regulations or, lacking the same, be in compliance with the manufacturer's recommendation. The chemical injection device shall be accurate to within 1% of maximum injection rates and easily calibrated and adjustable for all chemicals and all injection rates.

Sprinkler irrigation systems used to apply wastewater shall be designed with sprinkler nozzles of sufficient size to prevent clogging.

Design application rate and timing. Application rates shall follow label recommendations. Duration of chemical applications shall be the minimum length of time required to apply the chemicals and flush the pipelines.

Chemical application shall comply with runoff criteria set forth in the "Criteria Applicable to Efficient and Uniform Application of Water on Irrigated Lands" section.

Coefficient of uniformity. Use distribution and uniformity requirements stated in the "Criteria Applicable to Efficient and Uniform Application of Water on Irrigated Lands" section.

Sprinklers shall not be used to apply chemicals, nutrients, or wastewater in sustained wind conditions exceeding 10 mph or in wind conditions exceeding product label directions.

Additional Criteria Applicable to Improve Condition of Soil Contaminated with Salts and Other Chemicals

Design application depth. Base design application depth on crop rooting and salinity tolerance thresholds as defined in Chapter 2 in NEH 623 and Chapter 4 in NEH 652.

Design application rate. Use application rates that are less than soil intake rates to prevent ponding and runoff. Use distribution and uniformity requirements stated in the "Criteria Applicable to Efficient and Uniform Application of Water on Irrigated Lands" section.

Additional Criteria Applicable to Reduce Particulate Matter Emissions to Improve Air Quality

The installation and operation of sprinkler systems for confined animal pen dust control shall cover the majority of each pen area occupied by livestock (except for concrete feed bunk aprons and similar areas). The quality of applied water shall be fit for animal consumption.

Capacity and application depth. Sprinkler systems shall have capacity and flexibility to apply the design application depth in a cycle of 3 days or less. When determining application depth requirements, allow for reasonable application losses.

The minimum design application amount shall equal the maximum total daily wet-soil evaporation with allowances for moisture input to pen areas from animal manure and urine.

When used to suppress dust in confined animal pen areas, over-application and excessive sprinkler overlap shall be avoided to minimize runoff and to reduce odor, fly problems, and chronically wet areas.

Verify water supplies are adequate to meet other operating needs during sprinkler system operation

Water amendments. Chemical injectants labeled for dust suppression may be applied by sprinklers when the system has backflow prevention and anti-siphon devices.

When chemicals are applied through the sprinkler system, surface waters and livestock watering facilities shall be protected from direct application unless chemical labels indicate that direct application will not negatively impact human or animal health or water quality.

Distribution patterns and spacing. Spacing of sprinklers along laterals shall not be greater than 75% or less than 50% of wetted diameter listed in manufacturer's performance tables.

Spacing between laterals shall comply with the following criteria:

- For medium pressure sprinkler nozzles (50-75 psi), the spacing of laterals along the main line shall be no more than 90% and no closer than 70% of wetted diameter.
- For high pressure sprinklers (> 75 psi), the maximum distance between 2 sprinklers on adjacent lateral lines shall not exceed 100% of wetted diameter.

Risers. The risers shall be constructed in a manner that provides protection from corrosive soils, equipment damage, and livestock damage. Riser heights shall place the discharge sprinkler not less than 6 feet above ground surface. Risers shall be anchored and stabilized.

System valves and controllers. Due to high application rates, variable operating conditions, and needed system flexibility and control, use an automated control system to ensure maximum operating efficiency of the sprinkler system. Equip systems with a rain sensor connected to the control system to prohibit system operation during rainfall events.

Because wind may impact water distribution patterns, equip the automated system controller with timer overrides that allow the system to be operated manually during periods of calmer winds such as evening, nighttime, and early morning. The operating system shall provide the flexibility to change sprinkling duration in 1-minute increments and have a minimum of 6 start times per day to provide for adjustment for climate conditions.

Use automatic valves for the automated control system to facilitate operation of individual sprinkler nozzles. The valves shall be of a size and quality consistent with standard engineering practice. Incorporate zone isolation valves on laterals to allow partial system operation during periods of maintenance and repair. Install pressure regulators, pressure-compensating valves, or flow control devices at each sprinkler outlet.

In areas of uneven or sloping terrain, incorporate a control valve or low-head drainage device at each sprinkler to ensure that line drainage to the lowest sprinkler is minimized.

Additional Criteria Applicable to Reduce Energy Use

Provide an analysis that demonstrates reduction of energy use from practice implementation by documenting reduction in 1 or more of the following:

- Pressure.
- Flow rate.
- Seasonal hours of operation.
- Application depth.

Sprinkler operating pressure or flow rate reduction must translate to corresponding pumping plant discharge pressure or flow reduction.

The required analysis shall calculate energy reduction as the difference between average annual or seasonal energy use compared to previous operating conditions.

CONSIDERATIONS

All Systems, General

For guidance on selecting design application efficiency, see Chapter 11 in NEH 15 and NEH 652.

Refer to NEH 652 for additional guidance on using sprinkler irrigation systems for temperature control and chemigation.

The following items should be considered as applicable:

- Use of pressure regulators on a sprinkler system increases pumping cost because increased operating pressures are required upstream of each regulator/nozzle to overcome losses through the regulator, typically assumed to be 5 psi.
- Beneficial effects of conservation practices applied to limit translocation and runoff may diminish over the irrigation season.
- Systems designed to operate with multi-day irrigation sets should consider varied time increments or set times to balance the effects

of day and night temperature and wind patterns.

- Filter or screen irrigation water before it enters the system if it contains particulate matter, algae, or other material that could plug sprinkler nozzles.

Wastewater Application

- To avoid sprinkler plugging and reduce system design operating pressure when applying wastewater, solids should be removed by use of solid separators, screens, filters, 2-stage lagoons or waste holding ponds, or similar methods.
- The use of wastewater may reduce system life due to corrosion or abrasion. If fresh water is available, the system should be flushed after use.

Pivot/Linear Move

- The system effective irrigated area that is used in the computations should be based on a system radius from pad to the last sprinkler plus 75-80% of wetted radius of the last sprinkler or end gun.
- Elevation changes in the field have more impact on systems with lower system design pressures.
- Consider using pressure regulators even on relatively level ground if the system flow rate fluctuates significantly due to variable inlet water surface elevation or other reasons (for example, corner systems or end guns).
- Light, frequent applications can reduce runoff problems but may increase soil surface evaporation.
- Nozzle offsets or booms can be used to reduce peak application rates and tower wheel track rutting.
- J. Keller and R.D. Bliesner (2000) recommended end gun wetted sector angle settings of 135 degrees (L90, R45) for guns operated only in corners, and 150 degrees (L105, R45) for smaller end guns continuously operated.
- In order to conserve energy on pivot/lateral move systems, consider using an end gun booster pump in lieu of providing increased pressure to the entire system.
- Cyclic on/off operation of center pivot corner arm units and end guns impact system performance and application uniformity. A large end gun may reduce the average CU by 1 percent for each 1 percent of area covered past the main system hardware. The impact of transition speed and dual operating characteristics will impact pumping plant performance and can impact water supply and delivery system performance.
- Flexible drop tubes should be installed alternately on both sides of pivot/linear move span pipe when used in crop. Flexible drops should be weighted or secured in windy areas.
- Deflection of span pipes on center pivots and linear move systems will occur when the system is filled with water. This should be considered when determining drop lengths and nozzle heights. Any wheel track rutting depth will also affect nozzle height. When the system is charged with water, all nozzles installed on drops should be at the same relative height along the lateral.
- Nozzle discharges on center pivot/linear move systems can be diverted away from wheel tracks to reduce rutting.

Traveler Systems

- Consider reducing reel hose length to what is needed for the longest field. Standard supplied hose lengths are often longer than needed. The additional length reduces pressure for every application and wastes energy.

Solid Set and Periodic Hand Move

- Consider limiting pressure loss in laterals to a maximum of 10% of the operating pressure to improve water distribution uniformity.

<u>Particulate Matter Emissions Reduction</u>

- Scraping and removing manure between operations may reduce the amount of dust control needed. As a stand-alone practice, this may be sufficient to eliminate the need for sprinklers.
- Open-lot management practices can be applied that include scraping and removing manure in pens between occupations and shaping of the holding areas to prevent ponding water and chronically wet areas.
- Riser pipes used in lateral lines shall be high enough to minimize interference from surrounding structures.

PLANS AND SPECIFICATIONS

Plans and specifications for constructing sprinkler systems shall be in keeping with this standard and shall describe the requirements for properly installing the practice to achieve its intended purpose. As a minimum, plans shall include:

- Plan map showing location of system, application area, elevations, north arrow and scale.
- System design pressure and flow rate.
- Sprinkler location, type, nozzle size, operating pressure, and flow rate.
- Appurtenance location, type, size, and installation requirements.

Additional information regarding operation of the system will be included in the Irrigation Water Management Plan, Waste Recycling Plan and/or Nutrient Management Plan, Pest Management Plan, or Salinity Management/ Reclamation Plan (as applicable) for the practice purpose.

OPERATION AND MAINTENANCE

An operation and maintenance plan must provide specific instructions for operating and maintaining the system to ensure that it functions properly throughout its expected life span. It should also provide information regarding periodic inspections and prompt repair or replacement of damaged components. The plan, as a minimum, shall address the following:

- Periodic check and removal of debris and sediment as necessary from nozzles to ensure proper operation.
- Inspection or testing of pipeline and pumping plant components and appurtenances, as applicable.
- Regular testing of pressures and flow rates to ensure proper operation.
- Periodic checks of nozzles and spray heads for proper operation and wear.
- Routine maintenance of mechanical components in accordance with the manufacturer's recommendations.
- Prior to retrofitting any electrically powered equipment, electrical service must be disconnected and the absence of stray electrical current verified.

REFERENCES

Keller, J., and R. D. Bliesner. 2000. Sprinkle and Trickle Irrigation. p. 349-351. The Blackburn Press. Caldwell, NJ. ISBN: 1-930665-19-9.

Natural Resources Conservation Service. 1997. National Engineering Handbook, Part 652, *Irrigation Guide*.

Natural Resources Conservation Service. 1983. National Engineering Handbook, Section 15. *Irrigation*, Chapter 11, Sprinkle Irrigation.

Natural Resources Conservation Service. 1993. National Engineering Handbook, Part 623, *Irrigation*, Chapter 2, Irrigation Water Requirements.