Natural Resources Conservation Service
CONSERVATION PRACTICE STANDARD

IRRIGATION WATER MANAGEMENT

CODE 449
(ac)

Current	Proposed
DEFINITION The process of determining and controlling the volume, frequency, and application rate of irrigation water.	**DEFINITION** The process of determining, measuring, and controlling the volume, timing, and application rate of irrigation water.
PURPOSE This practice is used to accomplish one or more of the following purposes: • Improve irrigation water use efficiency • Minimize irrigation-induced soil erosion • Protect surface and ground water quality • Manage salts in the crop root zone • Manage air, soil, or plant microclimate • Improve poor plant productivity and health • Reduce energy use	**PURPOSE** This practice is used to accomplish one or more of the following purposes: • Improve irrigation water use efficiency. • Minimize irrigation-induced soil erosion. • Protect surface or groundwater quality. • Manage salts in the crop root zone. • Manage air, soil, or plant microclimate. • Improve poor plant productivity and health. • Provide data needed to manage efficient use of irrigation water to promote desired resource response and optimize use of available irrigation water supplies. • Reduce energy use.
CONDITIONS WHERE PRACTICE APPLIES This practice is applicable to all currently irrigated lands.	**CONDITIONS WHERE PRACTICE APPLIES** This practice is applicable to all currently irrigated lands.
CRITERIA **General Criteria Applicable to All Purposes** Develop an irrigation water management (IWM) plan that defines when irrigation is needed (timing) and the amount and rate of water to apply for each irrigation event.	**CRITERIA** **General Criteria Applicable to All Purposes** Develop an irrigation water management (IWM) plan that defines when irrigation is needed (timing) and the amount and rate of water to apply for each irrigation event.

Base the timing of irrigation on one or more of the following methods: • Evapotranspiration of the crop, using appropriate crop coefficients and reference evapotranspiration data, • Soil moisture monitoring, • Computerized irrigation scheduling, utilizing local real-time climate data, soil, and crop growth characteristics (e.g., remote telemetry data systems coupled with cloud-based irrigation scheduling using the soil-water balance method), • Plant monitoring (e.g., leaf water potential or leaf/canopy temperature measurements). Base the volume (depth) of water needed for each irrigation event on the following that are relevant to a crop or field: • Available water-holding capacity of the soil for the crop rooting depth, • Management allowed soil water depletion, • Current soil moisture status, • Current crop/forage growth stage, • Distribution uniformity of the irrigation event, • Water table contribution, • Computerized irrigation scheduling recommendation. For variable rate irrigation systems, such as center pivots, in addition, base the amount and application rate of irrigation water on spatially identified field parameters such as variations in past yield data, soils, crop growth, topography, or computerized irrigation scheduling recommendations. When irrigation water is not available on demand, such as when it is provided by an irrigation district, use the planned availability as a factor to determine the timing of the irrigation event. Adjust irrigation amounts appropriately to account for the periodic availability of water. In all situations where water is limited, ensure that the IWM plan will meet critical crop growth stages.	Base the timing of irrigation on one or more of the following methods: • Evapotranspiration of the crop, using an atmometer, pan evaporation, agricultural weather station's reference evapotranspiration (ET) data multiplied by a crop coefficient, weighing lysimeter, or energy balance equation methods. • Soil moisture or soil water tension monitoring. • Computerized irrigation scheduling, utilizing local real-time climate data, soil, and crop growth characteristics (e.g., remote telemetry data systems coupled with cloud-based irrigation scheduling using the soil-water balance method). • Plant monitoring (e.g., leaf water potential or leaf/canopy temperature measurements). Base the volume (depth) of water needed for each irrigation event on the following that are relevant to a crop or field: • Available water-holding capacity of the soil for the crop rooting depth. • Management allowed soil water depletion. • Current soil moisture status. • Current crop/forage growth stage. • Distribution uniformity of the irrigation event. • Water table contribution. • Computerized irrigation scheduling recommendation. For variable rate irrigation systems, such as center pivot systems integrated with precision zone placement technology, base the amount and application rate of irrigation water on spatially identified field parameters such as variations in past yield data, soils, salt concentration, crop growth, topography, or computerized irrigation scheduling recommendations. When irrigation water is not available on demand, such as when it is provided by an irrigation district, use the planned availability as a factor to determine the timing of the irrigation event. Adjust irrigation amounts appropriately to account for the periodic

In locations where rain is expected during the growing season, and where a soil-water balance is calculated, include measurements from an onsite rain gauge, interpolated predictions based on local weather stations, rain gauges, or other accurate method for determining local rainfall for the area under irrigation. For surface irrigation, apply irrigation water at a rate that achieves an acceptable distribution uniformity and minimizes irrigation-induced erosion.	availability of water. In all situations where water is limited, ensure that the IWM plan will meet critical crop growth stages. In locations where rain is expected during the growing season and where a soil-water balance is calculated, include measurements from an onsite rain gauge, interpolated predictions based on local weather stations, or another accurate method for determining local rainfall for the area under irrigation. For all methods of irrigation, apply irrigation water at a rate that achieves an acceptable distribution uniformity (DU) and minimizes irrigation-induced erosion. **Laws and Regulations** Plan, design, and implement this practice to comply with all Federal, State, Tribal, local laws, and regulations. **Safety** Follow all pertinent safety codes (e.g., OSHA) and manufacturer recommendations during structure or equipment installation.
Additional Criteria for the Protection of Surface and Ground Water Quality Plan the rate and volume of irrigation water to minimize the transport of sediment, nutrients, and chemicals to surface waters and ground water by— • Controlling the rate of water application to limit the transport of nutrients and chemicals through the soil profile to ground water. • Ensuring that the volume and rate of application does not result in damaging irrigation-induced erosion and/or contaminated runoff and offsite transport. Where the topography is steep enough to cause erosive flow velocities, provide permanent soil cover, increased crop	**Additional Criteria for the Protection of Surface and Groundwater Quality** Plan the rate and volume of irrigation water to minimize the transport of sediment, nutrients, and chemicals to surface waters and groundwater by— • Controlling the rate of water application to limit the transport of nutrients and chemicals through the soil profile to ground water. • Ensuring that the volume and rate of application does not result in damaging irrigation-induced erosion and/or contaminated runoff and offsite transport. • Scheduling the application of nutrients and chemicals to avoid excess leaching below the root zone to the groundwater and excess runoff to surface waters.

residue, and/or use polyacrylamide according to NRCS Conservation Practice Standard (CPS) Anionic Polyacrylamide (PAM) Application (Code 450) in lieu of or in combination with structural measures to control erosion. Do not conduct fertigation or chemigation operations if rainfall that may produce runoff or deep percolation is expected. Limit the application rate and volume of water to the amount necessary to apply the chemicals or nutrients to the soil depth recommended by the manufacturer. Limit the application of chemicals or nutrients to the minimum length of time required to deliver and flush the pipelines. Ensure that the irrigation and water delivery systems are equipped with properly designed and functioning valves and other components necessary to prevent backflows of nutrients or pesticides into the water sources. Base the timing and application of nutrients and/or pesticides on the criteria in NRCS CPS Nutrient Management (Code 590) and Pest Management Conservation System (Code 595), respectively.	Do not conduct chemigation operations if rainfall that may produce runoff or deep percolation is expected. Apply chemigation in accordance with all Federal, State, Tribal, local laws, and regulations. Limit the application rate and volume of water to the amount necessary to apply the chemicals or nutrients to the soil depth recommended by the manufacturer. Limit chemigation to the minimum length of time required to deliver and flush the pipelines. Ensure that the irrigation and water delivery systems are equipped with properly designed and functioning valves and other components necessary to prevent backflows of chemicals and nutrients into the water sources. Base the timing and application of nutrients and/or pesticides on the criteria in NRCS CPS Nutrient Management (Code 590) and Pest Management Conservation System (Code 595), respectively.
Additional Criteria for Managing Salts in the Crop Root Zone Ensure the irrigation application volume is sufficient to provide an appropriate salt balance in the soil profile. Base the determination of the required water volume on the leaching procedure contained in NRCS National Engineering Handbook (NEH) (Title 210), Part 623, Chapter 2, “Irrigation Water Requirements,” and 210-NEH, Part 652, “Irrigation Guide,” Chapters 3 and 13.	**Additional Criteria for Managing Salts in the Crop Root Zone** Ensure the irrigation application volume is sufficient to provide an appropriate salt balance in the soil profile. Base the determination of the required water volume on the leaching procedure contained in NRCS National Engineering Handbook (NEH) (Title 210), Part 623, Chapter 2, “Irrigation Water Requirements,” (210-NEH-632-2) and 210-NEH, Part 652, “Irrigation Guide,” Chapters 3 and 13.
Additional Criteria for Managing Air, Soil, or Plant Microclimate To provide protection from heat or cold, ensure that the irrigation system can apply the required rate of water as determined by the methodology contained in 210-NEH-623-2.	**Additional Criteria for Managing Air, Soil, or Plant Microclimate** To provide protection from heat or cold, ensure that the irrigation system can apply the required rate of water as determined by the methodology contained in 210-NEH-623-2.
Additional Criteria for Reduced Energy Use Provide analysis to demonstrate reduction of energy use from practice implementation.	**Additional Criteria for Reduced Energy Use** Provide analysis to demonstrate reduction of energy use from practice implementation.

Calculate the reduction of energy use as the average annual or seasonal energy reduction compared to previous operating conditions.	Calculate the reduction of energy use as the average annual or seasonal energy reduction compared to previous operating conditions.
	Additional Criteria for Closed Conduit Irrigation Flow Measurement The flow rate measured with a meter, or based on measurement of head or head differential will provide an in-field accuracy of ± 5 % within expected range of flow. Follow manufacturer recommendations supported by established scientific protocol to select application location, and appropriate type of metering device or structure that is suitable for the intended environment. Ensure manufacturer recommendations are followed regarding orientation and placement requirements for flow meters including straight pipe distance both upstream and downstream. Provide detail distances for various appurtenances, such as elbows, valves, and sudden enlargements, and contractions. Place the meter in the pipe in a position which is correct for the pipe diameter and wall thickness. In the absence of manufacturer recommendations a straight pipe section must extend at least 10 pipe diameters upstream and 5 pipe diameters downstream of the flow measurement device. Size and install each flow meter to ensure full pipe flow will be maintained through the water flow meter and water velocity in the measuring chamber will be within normal operating range for the water flow meter during system operation. Locate flow measurement devices as needed to report critical flow zone data. Design and install flow measurement devices and connections to be compatible with applicable criteria found in NRCS CPS Irrigation Pipeline (Code 430). Typical measurement devices for closed conduit conveyance application include, but are not limited to, turbine, propeller, acoustic, and magnetic flow meters. Use similar materials,

	whenever possible, for joints and connections between flow meters and pipeline. If dissimilar metals are used, protect the joints or connections against galvanic corrosion. If the material coefficients of thermal expansion are different, protect the connections from associated leaks and cracks. Protect pipe sections when flow meters are installed in pipes above ground. Use galvanized steel pipe or a suitable protective paint coating. Ensure plastic pipe is resistant to ultraviolet light throughout the intended life of the pipe or take measures to protect the pipe from damage due to ultraviolet light. **Support for Closed Conduit Irrigation Flow Measurement Devices** Provide secure physical support for measurement devices where needed, to provide stability against external and internal forces.
	Additional Criteria for Open Channel Irrigation Flow Measurement Equip water measurement structures with a staff gauge, or other suitable head measuring device installed at the specified location required for the measurement structure type. The flow rate measured based on the staff or head gauge will provide an in-field accuracy of ± 15% within the expected range of flows. Design structures using appropriate hydraulic tools, or software (e.g., WINFLUME). Select and design permanent structure based on site surveys, required hydraulic function, and soil and foundation investigations. NRCS standard drawings can be used as adapted to site conditions and functional requirements. Design and install flow measurement devices and connections to be compatible with applicable criteria found in relevant open channel NRCS CPSs.

	Ensure flow measurement structures provide sufficient freeboard to prevent overtopping during the maximum anticipated design flow rate. Provide a safe outlet or bypass if overtopping due to rainfall events or emergency water supply operations could cause damaging erosion or sedimentation. Typical measurement structures for open channel conveyance include, but are not limited to, flumes, weirs, and calibrated water control structures. Structural materials may include concrete, rock masonry, concrete blocks, wire mesh baskets (gabions), rock riprap, treated or redwood lumber, metal, steel, or steel pipe. Provide protective coatings for metal as needed. **Support for Open Channel Irrigation Flow Measurement Devices** Ensure sufficient footing, cutoff, weight, and strength for all structures to be stable against overturning, sliding, displacement, and foundation failure, based on all superimposed loads.
	Additional Criteria for Minimizing Irrigation-Induced Soil Erosion Where topography is steep enough to cause erosive flow velocities, provide permanent soil cover, increased crop residue, and/or use polyacrylamide according to NRCS Conservation Practice Standard (CPS) Anionic Polyacrylamide (PAM) Application (Code 450) in lieu of or in combination with structural measures to control erosion.
CONSIDERATIONS Consider the following when planning irrigation water management: • Increased crop residue left on the field will reduce the potential for irrigation-induced erosion, increase the infiltration of water into the soil, and reduce evaporation from the soil surface.	**CONSIDERATIONS** Consider the following when planning irrigation water management: • Increased crop residue left on the field will reduce the potential for irrigation-induced erosion, increase the infiltration of water into the soil, and reduce evaporation from the soil surface.

• There is a potential for spray drift and odors when applying agricultural and municipal waste waters. Time irrigation based on prevailing winds to reduce this potential. In areas of high visibility, consider irrigating at night. • The development of detailed topographic soil maps and the identification of environmentally sensitive areas can help with the development of site-specific irrigation plans that better meet crop needs while minimizing adverse environmental impacts. • Plan the location of end guns so that overspray will not reach public roads or other unintended locations. • Periodic inspection of irrigated areas for the presence of pesticides, animal wastes, or other contaminants prior to irrigation can allow these problems to be addressed before they cause a water quality problem. • The quality of irrigation water can adversely affect crops and soils. Testing and assessment of irrigation water can help to address adverse impacts of the water on crop quality, plant development, and soil properties such as crusting, pH, permeability, salinity, and structure. • Avoid operating heavy equipment on wet soils to minimize soil compaction. • To reduce the potential for ground water contamination, schedule salt leaching events to coincide with low levels of residual soil nutrients and pesticides. • Manage water so it does not drift or come in direct contact with surrounding electrical lines, supplies, devices, controls, or components that could cause loss of electrical power or the creation of an electrical safety hazard to humans or animals. • Consider how the interruption of power to irrigation systems from load control, interruptible power schedules, repair and maintenance downtime, and harvest downtime may change the plans for irrigation water management.	• There is a potential for spray drift and odors when applying agricultural and municipal waste waters. Time irrigation based on prevailing winds to reduce this potential. Consider irrigation at night to reduce evaporation and human exposure. • The development of detailed topographic soil maps and the identification of environmentally sensitive areas can help with the development of site-specific irrigation plans that better meet crop needs while minimizing adverse environmental impacts. • Plan the location of sprinklers and end guns so that overspray will not reach public roads or other unintended locations. • Periodic inspection of irrigated areas for the presence of pesticides, animal wastes, or other contaminants prior to irrigation can allow these problems to be addressed before they cause a water quality problem. • The quality of irrigation water can adversely affect crops and soils. Testing and assessment of irrigation water can help to address adverse impacts of the water on crop quality, plant development, and soil properties such as crusting, pH, permeability, salinity, and structure. • Avoid operating heavy equipment on wet soils to minimize soil compaction. • To reduce the potential for ground water contamination, schedule salt leaching events to coincide with low levels of residual soil nutrients and pesticides. • Manage water so it does not drift or come in direct contact with surrounding electrical lines, supplies, devices, controls, or components that could cause loss of electrical power or the creation of an electrical safety hazard to humans or animals. • Consider how the interruption of power to irrigation systems from load control, interruptible power schedules, repair and maintenance downtime, and harvest downtime may change the plans for irrigation water management.

• The use of new technologies for data collection such as drones, advanced imaging technology, remote sensing technology, yield monitoring, and data logging to calculate water use can lead to more efficient water application. • The use of energy saving technologies, such as low energy precision application irrigation and use of alternative energy sources can result in significant energy saving versus conventional methods. • Crop species selection in situations where drought or water deficits are recurrent.	• The use of new technologies for data collection such as drones, advanced imaging technology, remote sensing technology, yield monitoring, and data logging to calculate water use can lead to more efficient water application. • The use of energy saving technologies, such as low energy precision application irrigation and use of alternative energy sources can result in significant energy saving versus conventional methods. • Crop species selection in situations where drought or water deficits are recurrent. • Fluid velocity, sediment load, debris, and site characteristics when making selection of device or structure for flow measurement. • Managing water levels in rice fields to minimize greenhouse gas production.
PLANS AND SPECIFICATIONS Prepare plans and specifications that describe the requirements for applying the practice according to the requirements of this standard. As a minimum, include in the plans and specifications— • A plan view showing the layout of the irrigation system including irrigated areas, planned crops, soils, pipelines, and location and installation information for any moisture sensors, rainfall gauges, or other sensing equipment. • Methods to be used to measure or determine the flow rate and volume of the irrigation applications. • Documentation of the scientific method used for scheduling the timing and amount of irrigation applications. • The seasonal or annual planned water application volumes by crop. • The management allowable depletion and depth of the managed crop root zone for each crop.	**PLANS AND SPECIFICATIONS** Prepare plans and specifications that describe the requirements for applying the practice according to the requirements of this standard. As a minimum, include in the plans and specifications— • A plan view showing the layout of the irrigation system including irrigated areas, planned crops, soils, pipelines, and location and installation information for any moisture sensors, flow measurement devices or structures, rainfall gauges, or other sensing equipment. • Site specific construction drawings and specifications that describe in writing the installation of the flow measurement device or structure. • Profile view of each open channel flow measurement device or structure. • Flow measurement device sizes, materials, expected measurement accuracy, joint requirements, calibration procedure, and any requirements for pressure testing.

• An estimate of the irrigation system distribution uniformity, based on testing, evaluation, or observation. • The specific soil moisture monitoring objectives if soil moisture sensors are used. Indicate how data from the soil moisture sensor locations and depths will be considered to make field-wide irrigation decisions. • Information on how to recognize irrigation-induced erosion and how to mitigate it.	• Methods to be used to measure or determine the flow rate and volume of the irrigation applications. • Documentation of the scientific method used for scheduling the timing and amount of irrigation applications. • The seasonal or annual planned water application volumes for each irrigation zone. • The management allowable depletion (MAD) and depth of the managed crop root zone for each managed irrigation zone. • An estimate of the irrigation system distribution uniformity, based on testing, evaluation, or observation. • The specific soil moisture monitoring objectives if soil moisture sensors are used. Indicate how data from the soil moisture sensor locations and depths will be considered to make irrigation decisions. • Information on how to recognize irrigation-induced erosion and description of safeguards to protect surface and groundwater quality, as needed.
OPERATION AND MAINTENANCE Prepare an operation and maintenance (O&M) plan for the operator. As a minimum, include in the O&M plan: • Record keeping documents to be used by the operator to record irrigation water management activities. • Requirements for recording each irrigation event, including the amount or depth of water applied, duration of the event, and the date of application. • Requirements for recording the methods used for determining the timing and amount of irrigation events. • Requirements for recording other pertinent data used to implement the irrigation water management plan.	**OPERATION AND MAINTENANCE** Prepare an operation and maintenance (O&M) plan for the operator. As a minimum, include in the O&M plan: • Record keeping documents to be used by the operator to record irrigation water management activities. • Requirements for recording each irrigation event, including the amount or depth of water applied, duration of the event, and the date of application. • Requirements for recording the methods used for determining the timing and amount of irrigation events. • Requirements for recording other pertinent data used to implement the irrigation water management plan.

• Reference other O&M plans for the irrigation equipment and water delivery systems used.	• Requirements for flow measurement frequency and recording. • Schedule for inspection, maintenance, and accuracy testing of installed flow measurement devices or structures. • Reference other O&M plans for the irrigation equipment and water delivery systems used.
REFERENCES Glenn, E.P., P.L. Nagler, and A.R. Huete. 2010. Vegetation Index Methods for Estimating Evapotranspiration by Remote Sensing. Surveys in Geophysics 31:531-555. DOI 10.1007/s10712-010- 9102-2 Schimmelpfenning, D. 2016. Farm Profits and Adoption of Precision Agriculture. Economic Research Report Number 217. Economic Research Service. Washington, D.C. Stubbs, M. and P. McGee. 2016. Irrigation in U.S. Agriculture: On-Farm Technologies and Best Management Practices. Congressional Research Service. Washington, D.C. USDA NRCS. 2007. Technical Note (Title 190), Agronomy Technical Note 1, Precision Agriculture: NRCS Support for Emerging Technologies. Washington, D.C. https://directives.sc.egov.usda.gov/ USDA NRCS. 1993. National Engineering Handbook (Title 210), Part 623, Chapter 2, Irrigation Water Requirements. Washington, D.C. https://directives.sc.egov.usda.gov/. USDA NRCS. 1997. National Engineering Handbook (Title 210), Part 623, Chapter 9, Water Measurement. Washington, D.C. https://directives.sc.egov.usda.gov/. USDA NRCS. 1997. National Engineering Handbook (Title 210), Part 652, Irrigation Guide. Washington, D.C. https://directives.sc.egov.usda.gov/.	**REFERENCES** Glenn, E.P., P.L. Nagler, and A.R. Huete. 2010. Vegetation Index Methods for Estimating Evapotranspiration by Remote Sensing. Surveys in Geophysics 31:531-555. DOI 10.1007/s10712-010- 9102-2 Schimmelpfenning, D. 2016. Farm Profits and Adoption of Precision Agriculture. Economic Research Report Number 217. Economic Research Service. Washington, D.C. Stubbs, M. and P. McGee. 2016. Irrigation in U.S. Agriculture: On-Farm Technologies and Best Management Practices. Congressional Research Service. Washington, D.C. USDA NRCS. 1993. National Engineering Handbook (Title 210), Part 623, Chapter 2, Irrigation Water Requirements. Washington, D.C. https://directives.sc.egov.usda.gov/. USDA NRCS. 1997. National Engineering Handbook (Title 210), Part 623, Chapter 9, Water Measurement. Washington, D.C. https://directives.sc.egov.usda.gov/. USDA NRCS. 1997. National Engineering Handbook (Title 210), Part 652, Irrigation Guide. Washington, D.C. https://directives.sc.egov.usda.gov/. USDA NRCS. 2007. Technical Note (Title 190), Agronomy Technical Note 1, Precision Agriculture: NRCS Support for Emerging Technologies. Washington, D.C. https://directives.sc.egov.usda.gov/.

	USDA NRCS. 2022. National Engineering Handbook (Title 210), Part 634, Chapter 5, Water Flow Measurement. Washington, D.C. https://directives.sc.egov.usda.gov/.