NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD
ARIZONA

IRRIGATION SYSTEM, MICROIRRIGATION

(No. and Ac.)

CODE 441

DEFINITION

An irrigation system for frequent application of small quantities of water on or below the soil surface: as drops, tiny streams or miniature spray through emitters or applicators placed along a water delivery line.

PURPOSE

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

- To efficiently and uniformly apply irrigation water and maintain soil moisture for plant growth.
- To prevent contamination of ground and surface water by efficiently and uniformly applying chemicals.
- To establish desired vegetation

CONDITIONS WHERE PRACTICE APPLIES

On sites where soils and topography are suitable for irrigation of proposed crops and an adequate supply of suitable quality water is available for the intended purpose(s).

Microirrigation is suited to vineyards, orchards, field crops, windbreaks, gardens, greenhouse crops, and residential and commercial landscape systems. Microirrigation is also suited to steep slopes where other methods would cause excessive erosion, and areas where other application devices interfere with cultural operations.

Microirrigation is suited for use in providing irrigation water in limited amounts to establish desired vegetation such as windbreaks, living snow fences, riparian forest buffers, and wildlife plantings.

This practice standard applies to systems with design discharge less than 60 gal/hr at each individual lateral discharge point.

Conservation Practice Standard 442, Irrigation System, Sprinkler applies to systems with design discharge of 60 gal/hr or greater at each individual lateral discharge point.

CRITERIA

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

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

***Laws and Regulations**. Design, installation, and operation of this practice shall comply with all federal, state, Tribal and local laws, rules, and regulations. Laws and regulations of particular concern include those involving water rights, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.*

The owner is responsible for securing necessary permits and water rights, complying with all

laws and regulations, and meeting legal requirements applicable to the installation, operation, and maintenance of this practice and associated structures.

Cultural Resources and Wildlife Habitat. *Impact to cultural resources, wetlands and Federal and state protected species shall be evaluated and avoided or minimized to the extent practicable during planning, design and implementation of this conservation practice in accordance with established National policy, General Manual (GM) Title 420-Part 401; Title 450-Part 401, Title 190-Parts 410.22 and 410.26, National Planning Procedures Handbook (NPPH), National Cultural Resources Procedures Handbook (NCRPH), National Food Security Act Manual (NFSAM), and the National Environmental Compliance Handbook (NECH).*

General Criteria Applicable to All Purposes

The system shall be designed *as an integral part of an overall conservation land use plan* to uniformly apply water and/or chemicals while maintaining soil moisture within a range for good plant growth without excessive water loss, erosion, reduction in water quality, or salt accumulation *based on the capabilities of the land, irrigation water supply, crop requirements and the needs of the operator. The system selection shall be based on a site evaluation, anticipated operating conditions, and verification that soils and topography are suitable for the intended purpose(s).*

Microirrigation systems consist of point-source emitter (drip, trickle, and bubbler), surface or subsurface line-source emitter, basin bubbler, and spray or mini sprinkler systems.

The system shall include all irrigation appurtenances necessary for proper operation. Appurtenances shall be sized and positioned in accordance with sound engineering principles and site-specific features.

Appurtenances include but are not limited to totalizing flow measurement devices, water filtration, air vent valves, vacuum relief valves, pressure relief valve(s), water control valve(s), pressure gauges, pressure regulators, and pressure reducers.

For the purposes of this standard and in the absence of manufacturer data or documentation, drip tape and/or tubing shall be categorized as "thin wall" (25-mil and less) or "heavy wall" (above 25-mil).

Water Quality. The irrigation water supply shall be tested and assessed for physical, chemical and biological constituents to determine suitability and treatment requirements for use in a microirrigation system. *Please refer to NRCS AZ Fact Sheet for Water Testing, Assessment of Water Quality for Microirrigation (reference 7) for water quality criteria.*

Water quality information shall be made available to the designer and irrigation manager during the early planning stages so suitable system components are incorporated into the design.

Emitter discharge rate. The design discharge rate of applicators shall be determined based on manufacturer's data for expected operating conditions. The discharge rate shall not create runoff within the immediate application area.

For bubbler irrigation, a basin beneath the plant canopy shall be required for water control, and applications shall be confined to the basin area.

Number and spacing of emitters. The number and spacing of emitters along a lateral line shall be adequate to provide water distribution to the plant root zone and percent plant wetted area (P_w). Procedures found in *the National Engineering Handbook (NEH) Part 623, Chapter 7, Trickle Irrigation* (reference 4) shall be used to calculate P_w.

Operating pressure. The design operating pressure shall be in accordance with published manufacturer recommendations. The system operating pressure must compensate for pressure

losses through system components and field elevation effects.

Emitter manufacturing variability. The manufacturer's coefficient of variation (C_V) shall be obtained and used to assess the acceptability of a particular product for a given application.

The C_V shall be less than 0.07 for point source emitters and less than 0.20 for line source emitters.

Flow Measurement. *A flow meter shall be installed downstream of the pump/filter station to manage water applications and for on-going evaluation of system performance. The meter shall display the instantaneous flow rate (i.e. gallons per minute, cubic feet per second) and total volume (i.e. acre-feet). Installation shall be per manufacturer's recommendations regarding length of straight pipe sections, straightening vanes, pipe diameter, etc.*

Allowable pressure variations.
Manifold and lateral lines. Manifold and lateral lines, operating at the design pressure, shall be designed to provide discharge to any applicator in an irrigation subunit or zone operated simultaneously such that they will not exceed a total variation of 20 percent of the design discharge rate. Internal pressure shall not exceed manufacturer recommendations during any phase of operation.

Main and submain lines. Main and submain lines shall be designed to supply water to all manifold and lateral lines at a flow rate and pressure not less than the minimum design requirements of each subunit. Adequate pressure shall be provided to overcome all friction losses in the pipelines and appurtenances (valves, filters, etc.). Mains and submains shall maintain flow velocities less than 5 ft/sec during all phases of operation, unless special consideration is given to flow conditions and measures taken to adequately protect the pipe network against surge.

Main and submain lines shall be designed and installed according to criteria in *NRCS, Conservation Practice Standard 430, Irrigation Pipeline* (reference 3).

Emission Uniformity. Pipe sizes for mains, submains, and laterals shall maintain subunit (zone) emission uniformity (EU) within recommended limits as determined by procedures contained in *NEH Part 623, Part 623, Chapter 7, Trickle Irrigation* (reference 4).

Filters. A filtration system (filter element, screen, strainer, or filtration) shall be provided at the system inlet. Under clean conditions, filters shall be designed for maximum head loss of 5 psi. Maximum design head loss across a filter before cleaning shall be based on manufacturer recommendations. In the absence of manufacturer data, maximum permissible design head loss across a filter is 7 psi before filter cleaning is required.

The filter shall be sized to prevent the passage of solids in sizes or quantities that might obstruct the emitter openings. Filtration systems shall be designed to remove solids based on emitter manufacturer recommendations. In the absence of manufacturer data or recommendations, filtration systems shall be designed to remove solids equal to or larger than one-tenth the emitter opening diameter.

The filter system shall provide sufficient filtering capacity so that backwash time does not exceed 10% of the system operation time. Within this 10% time period, the pressure loss across the filter shall remain within the manufacturer's specification and not cause unacceptable EU.

Filter/strainer systems designed for continuous flushing shall not have backwash rates exceeding 1.0% of the system flow rate or exceeding the manufacturer's specified operational head loss across the filter.

Air/Vacuum relief valves. Vacuum relief shall be designed and installed to prevent ingestion of

soil particles if there are summits in system laterals.

Large volume air *vent*/vacuum relief valves shall be installed on both sides of all block or manifold water supply control valves and *upstream of all check valves.*

Design of all air vent, pressure relief/release valves, combination air valves, etc. shall be per Arizona Conservation Practice Standard 430, Irrigation Pipeline (reference 3).

Pressure regulators. Pressure regulators shall be used where topography and the type of applicator dictate their use. Pressure regulators shall not be planned to compensate for improperly designed pipelines.

System flushing. Appropriate fittings shall be installed above ground at the ends of all mains, submains, and laterals to facilitate flushing. The system shall be designed and installed to provide a minimum flow velocity of 1 ft/sec during flushing. During flushing, submain and manifold (pipelines located downstream from a control valve) velocities shall not exceed 7 ft/sec velocity. Each flushing discharge outlet shall include a pressure gauge and/or Schrader valve tap.

Management Plan. *An Irrigation Water Management plan, meeting NRCS Conservation Practice Standard 449, Irrigation Water Management, shall be developed for this practice.*

Materials. *Material selection shall meet minimum recommendations as specified by applicable Arizona Conservation Practice Standards and Material Specifications and/or manufacturer recommendations.*

Where recommended by the manufacturer or supplier, PVC materials may be installed above ground at the filter/pump station, manifolds and flush drain locations. PVC material shall be protected from UV degradation by paint or wrapping, suitable to the material and applied per manufacturer recommendations.

Materials made of, or which has been exposed to hazardous or potentially harmful materials, such as asbestos, shall not be used.

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

Preliminary site assessment, investigation or reconnaissance to determine the scope and complexity of the site shall include:

1. *Soil or geological investigation to determine soil conditions, including type, texture, intake rate, available water holding capacity (AWC), characteristics (physical and chemical properties), depths, topography, water tables, inhibiting layers, etc. Classification shall be by the Unified Soil Classification System (SM, CL, etc.), texture (silty sand, lean clay, etc.).*
2. *Identify crop types, tillage practices, water use (peak consumptive use).*
3. *Water source (i.e., available flow rate, volume, seasonal variation) and water quality test results (required).*
4. *Field and irrigation system layout.*
5. *Verify appropriate state or local laws for permitting and approval requirements and notify landowner of his/her responsibilities.*
6. *Verification or certification of used materials (if any).*

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

1. *Site topography, as needed to show the irrigation system position and component layout, irrigation methods, physical features of the site (field boundaries and slope), including existing features/practices, ground elevations, location of any utilities or markers, etc.*
2. *Profile along the centerline of the pipeline to determine critical control elevations and lengths. Where applicable, USGS 7.5-minute topographic Quadrangles combined with aerial photography and field verification may*

be used, provided design analysis verifies minimum hydraulic criteria (pressures and flows) are achievable at all locations.

3. *All pertinent water surface elevations, i.e. water supply ditch/reservoir/well, check structures, high water marks;*
4. *If applicable, a permanent benchmark(s) shall be set and described. Preferably, the elevations and coordinates should be based on a local (assumed) or coordinate system (State or grid) and clearly stated on the plan. Datum may be in the form of Northing and Easting coordinates or Longitude and Latitude.*

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

1. *Determination of system requirements as related to meeting the needs of the intended use (irrigation system efficiency or application rates, quantity and timing of irrigation water availability, crop water requirements, deficit irrigation, etc). Determine the required total head and system flow (gpm) at filter discharge (psi) and flushing velocities.*
2. *Perform a hydraulic analysis of the system using approved irrigation software (Drip design spreadsheet or approved equal) simulating the proposed irrigation system. Include support documentation for input parameters and values used.*
3. *Field and zone size, including number of blocks, concurrent zones or blocks watered concurrently and application per zone (flow rates, pressures, uniformity, duration, etc.). For each zone/block include:*
   a. *Type of lateral or drip tape, inside diameter, spacing, burial depth (if applicable).*
   b. *Emitter type (make, model, coefficient of variance, discharge coefficients) and spacing.*
   c. *Determine the minimum, maximum and average emitter discharge rate, pressure and location.*
   d. *Design manifold inlet pressures (downstream of valves).*
   e. *Emission uniformity for zone or lateral.*
4. *Irrigation fittings and appurtenance (type, size, pressure settings, capacity, head loss, location) shall be designed in accordance with applicable conservation practice standards or from published manufacturer literature.*
5. *Type and size of filter system, including make, model and capacity (gpm); head loss across filter, back-flushing time required (% of total operating time), continuous back flush rates (if applicable).*
6. *Size the power or pump unit to meet system requirements.*
7. *Material estimates (material volume computations), includes estimates of earthwork, pipe, fittings and appurtenances, concrete, vegetative components, etc.*
8. *Subsidiary and applicable components shall be designed in accordance with applicable conservation practice standards (i.e., pipelines shall meet the requirements of Conservation Practice 430 – Irrigation Pipeline, etc.);*

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

Contractors performing work under this practice shall abide by all Federal, State or Tribal laws or criteria, and must be licensed by

the state board of technical registers where the work is being implemented.

Criteria Applicable to Efficiently and Uniformly Apply Irrigation Water

Depth of application. Net depth of application shall be sufficient to replace the water used by the plant during the plant peak use period or critical growth stage. Gross depth of application shall be determined by using field application efficiencies consistent with the type of microirrigation system planned. Applications shall include adequate water for leaching to maintain a steady state salt balance.

System capacity. The system shall have either (1) a design capacity adequate to meet peak water demands of all crops to be irrigated in the design area, or (2) enough capacity to meet water application requirements during critical crop growth periods when less than full irrigation is planned. The rationale for using a design capacity less than peak daily irrigation water requirement shall be fully explained and agreed upon by the end user. Design capacity shall include an allowance for reasonable water losses (evaporation, runoff, and deep percolation) during application periods.

The system shall have the capacity to apply a specified amount of water to the design area within the net operation period. Minimum system design capacity shall be sufficient to deliver the specified amount of water in 90% of the time available, but not to exceed 22 hours of operation per day.

Subsurface Drip Irrigation (SDI). Tubing depth and spacing are soil and crop dependent. Emitter line depth shall consider the auxiliary irrigation methods used for leaching, germination, and initial development. Maximum lateral line distance from the crop row shall be 24 inches for annual row crops and 48 inches for vineyard and orchard crops. EU shall be designed for a minimum of 85 percent.

Criteria Applicable to Preventing Contamination of Ground and Surface Water

Chemigation and Chemical Water Treatment. System EU shall not be less than 85 percent where fertilizer, pesticides, or treatment chemicals are applied through the system.

Backflow prevention devices shall be provided on all microirrigation systems, *including those* equipped for chemical injection. *Wells and public water sources shall be protected by spring-loaded check valves and a low pressure drain (which opens and drains any remaining liquid onto the ground when the pressure drops) on the bottom of the upstream section.*

Injectors (chemical, fertilizer or pesticides) and other automatic operating equipment shall be located and installed in accordance with manufacturer's recommendations and include integrated back flow prevention protection.

Chemigation shall be accomplished in the minimum length of time needed to deliver the chemicals and flush the pipelines. Application amounts shall be limited to minimum amount necessary, and rate shall not exceed maximum rate recommended by chemical label.

Proper maintenance and water treatment shall be followed to prevent clogging based upon dripper and water quality characteristics.

Irrigation water supply tests shall be used to plan for addressing or avoiding chemical reactions with injected chemicals to prevent precipitate or biological plugging.

Criteria Applicable to Establishing Desired Vegetation

System capacity. The system shall have design capacity adequate to provide supplemental water at a rate that will insure survival and establishment of planned vegetation for a period of at least 3 years. The system shall have the capacity to apply the specified amount of water to the design area within the net operation period.

Gross application volume per plant shall be determined using field application efficiency consistent with the type of microirrigation system planned. If a need is indicated by water test results, applications shall include adequate water for leaching to maintain a steady state salt balance.

Microirrigation systems installed solely to deliver supplemental water for establishment of windbreaks or riparian vegetation shall be designed to deliver a minimum of eight gallons per tree or shrub per week to assist in the establishment process. Design net application volumes per plant are dependent on the species of tree or shrub and the age (first, second, or third year).

Drip lateral lines installed on the ground surface shall be placed along the plant row(s) in a serpentine pattern to allow for expansion and contraction of the line while keeping the emitter close to the tree or shrub. Above ground drip line shall be pinned or anchored to prevent the line from being dislodged or moved away from the trees or shrubs.

Windbreaks shall be planned, designed, and installed according to NRCS, Conservation Practice Standard, Windbreak-Shelterbelt Establishment, Code 380.

When lateral emitter spacing or capacities vary with each row, the laterals must be designed separately.

Operation and maintenance items specific to vegetation establishment are included in Chapter 6 of *the National Engineering Handbook, Part 652, Irrigation Guide* (reference 2).

CONSIDERATIONS

In the absence of local experience field application efficiency (E) of 90% should used to estimate system capacity.

In arid climates with subsurface systems natural precipitation and/or stored soil water is sometimes inadequate to provide crop germination. Special provisions should be made for germination (i.e. portable sprinklers), or the microirrigation system should apply water at a rate sufficient to adequately wet the soil to germinate seeds or establish transplants *unless it is stated in writing that other provisions will be made*. The depth of subsurface systems on annual crops should be limited by the ability of the system to germinate seeds, unless other provisions are made for this function.

Potential rodent damage should be considered when selecting materials and deciding on above or below ground system installation.

Chemigation may or may not be required at the same time the plant requires irrigation, which may affect the economics of chemigation. Weather conditions should be considered before applying chemicals. Pest or nutrient management planning should address the timing and rate of chemical applications.

Field shape and slope often dictate the most economical lateral direction. Laying laterals down slope can allow for longer lateral run lengths and/or lateral size reduction. Uneven topography may require use of pressure compensating emitters.

For terrain slopes steeper than 5%, lateral lines should be laid along the field contour and pressure-compensating emitters specified or pressure control devices used along downslope submains at lateral inlets.

Economic assessments of alternative designs should include equipment and installation as well as operating costs.

Longer, less frequent irrigations of windbreaks during establishment are recommended to encourage deeper root development that increases drought tolerance.

Chemicals should not be applied if rainfall is imminent.

Installation and operation of microirrigation systems have the potential to save energy as a

result of reduced seasonal irrigation application, and in some situations reduced operating pressures.

Microirrigation can influence runoff and deep percolation by raising the soil moisture level and decreasing available soil water storage capacity, increasing the probability of runoff or percolation below the root zone from storm events. The movement of sediment, soluble chemicals, and sediment-attached substances carried by runoff may affect surface water quality. The movement of dissolved substances below the root zone may affect groundwater quality. Microirrigation may also affect downstream flows or aquifers and the amount of water available for other water uses.

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

***Vegetation**. Where applicable, disturbed areas shall be established with vegetation or otherwise stabilized as soon as practical after construction. Seedbed preparation, seeding, fertilizing, and mulching shall conform to Arizona Conservation Practice Standard 342, Critical Area Planting.*

PLANS AND SPECIFICATIONS

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

Construction plans shall include all components needed for the safe operation of the proposed improvements such as railing, fencing, or warning signs as appropriate. The plans shall address operations near existing utilities, trench excavations and any other items related to construction of the structure that may pose a safety risk to those involved.

*Development of p*lans and specifications *will be guided by the National Engineering Handbook, Part 650, the Engineering Field Handbook, Chapter 5, and shall be in accordance with the National Engineering Manual, Parts 541 and 542, and* shall be prepared for each specific site in accordance with this standard and whose construction documents shall describe the requirements for applying the practice to achieve its intended use. *The drawings and specifications shall include:*

- *Project location map, including section, township and range, North arrow, cooperator/owner acknowledgement and certification signature blocks, engineering job class (cover sheet);*
- *References that the owner/cooperator are responsible for all permits, rights-of-way, easements and the contact, coordination and location determination of any existing utilities or clearances (buried utility disclaimer);*
- *If applicable, a map showing the location of the practice(s) or system in reference to a known or established benchmark or reference point with the location, description and elevation clearly shown. Topographical features and/or controls shall be shown, showing tie in with existing or other planned practices;*
- *Field surveys and notes, soil investigations or geologic soil boring locations and soil classifications, earthwork or material estimates/quantities (as needed);*
- *System overview and layout (i.e., location and orientation of practice in relation to existing or planned facilities; identify the water source (reservoir, well, etc.); stationing and alignment for all underground conveyance pipelines; field or zones served (label with type and number of drip tapes/tubing required); fittings and/or appurtenances (filter, chemical injection, pump, flow meter, manifolds, valves, air vents, etc.); size, type and quality of all emitters or drip tape; vegetative requirements; construction/installation criteria, including State and Federal [OSHA] safety requirements, etc.);*
- *A stationed profile along the pipe centerline showing the original ground surface; pipe grades; hydraulic and static grade lines; design flow; all mainlines, submains, manifolds, headers, and flush lines shall include sizes (diameters), lengths, type and pressure rating.*

- *Appurtenance and/or fitting details (i.e., valves, air vents, regulators, pressure relief, pressure regulators, etc.), as required, for proper system functionality. Location and details for system flushing.*
- *Construction details/requirements for the inlet structure, pump, and filter.*
- *Construction notes, details or specifications to clarify a component and furnish directions or site specific requirement, i.e. quantities of materials.*
- *Use Arizona Construction and Material Specifications for each item of work and material, as applicable and available. Additional specifications may need to be written to provide full material and installation instructions. Fill in blanks and add or delete items from the specifications to make them fit the job as needed.*

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

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

OPERATION AND MAINTENANCE

A site specific operation and maintenance (O&M) plan shall be developed and reviewed with the landowner/operator. The O&M plan shall provide specific instructions for operating and maintaining the system to ensure that it functions properly, including reference to periodic inspections and the prompt repair or replacement of damaged components. Operation and Maintenance Plan should include but is not limited to:

- Install flow meter and monitor water application.
- Clean or backflush filters when needed.
- Flush lateral lines at least annually *or more frequently as needed to maintain an acceptable EU*
- Check applicator discharge often; replace applicators as necessary.
- *Allow the pipe to fill gradually when being put into use after shut down or draining. Filling at the specified rate requirements and opening/closing valves to prevent excessive water hammer.*
- Check operating pressures often; a pressure drop (or rise) may indicate problems.
- Check pressure gauges to ensure proper operation; repair/replace damaged gauges.
- Inject chemicals as required to prevent precipitate buildup and algae growth.
- Check chemical injection equipment regularly to ensure it is operating properly.
- Check and assure proper operation of backflow protection devices.
- *Check and re-apply protective coating on all above ground PVC materials as needed (minimum every two years).*
- *Maintaining erosion protection at outlets and around facilities to prevent surface ponding by grading to remove depressions.*
- *Checking for debris, minerals, algae and other materials which may restrict system flow;*
- *Requirements for cleaning and repairing of screens and structures, including the periodic check and repair all valves, gates and regulators to the system requirements following the manufacturer's recommendations.*
- *Remove all foreign debris that hinders system operation.*
- *Requirements for off-season storage and handling of pipe, including draining and/or providing for cold weather operation of the system.*
- *Limit livestock usage to periods that permit use without damage.*
- *If fences are installed, they shall be maintained to provide warning and/or prevent unauthorized human or livestock entry.*
- *Limit traffic over the pipeline to designated sections that were designed for traffic loads and avoid travel over pipelines by tillage equipment when the soil is saturated.*

- *Immediately repair any damage from vandalism, vehicles, rodents or livestock to any outlets and appurtenances.*
- *Eradicate or otherwise remove all rodents or burrowing animals that have or may potentially damage any part of the delivery or application facilities. Immediately repair any damage caused by their activity;*
- *Immediately repair any damage resulting from vandalism, vehicles, livestock or wildlife;*

REFERENCES

- Design and Installation of Microirrigation Systems, American Society of Agricultural *and Biological* Engineers (ASA*B*E), ASAE EP405.1, February 2003. *APR1988 (R2008)*
- *National Engineering Manual, USDA, Natural Resources Conservation Service*
- *Kings Handbook of Hydraulics*
- National Engineering Handbook *(NEH)*, Part 652 – Irrigation Guide; *Part 636 – Structural Engineering, Chapter 52; Part 634 – Hydraulic Engineering; USDA, Natural Resources Conservation Service*
- National Engineering Handbook, Part 623, Chapter 7, Trickle Irrigation, 1984; and Chapter 2, Irrigation Water Requirements, 1993
- *National Engineering Handbook - Part 650,* Engineering Field Handbook, *Chapter 1 – Engineering Surveys; Chapter 2 – Hydrology; Chapter 3 – Hydraulics; Chapter 4 – Elementary Soils Engineering; Chapter 5 – Preparation of Engineering Plans; Chapter 15 – Irrigation; and Chapter 17 – Construction & Construction Materials*
- NRCS, *Arizona* Conservation Practice Standards; 430 – Irrigation Pipeline; *443 – Irrigation System, Surface and Subsurface; and 449 – Irrigation Water Management*
- *NRCS, Fact Sheet for Water Testing, Assessment of Water Quality for Micro Irrigation, AZ, February 2010.*
- *USDA-NRCS, TR-62 – Engineering Layout, Notes, Staking and Calculations; TR-77, Design & Installation of Flexible Conduits*
- *National Environmental Compliance Handbook*
- *General Manual, Title 420-Part 401, Title 450-Part 401, Title 190-Parts 410.22 and 410.26*
- *National Planning Procedures Handbook*