

Irrigation Management Practices

Checklist for Oregon

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Irrigation Management Practices Checklist for Oregon

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Introduction

This is a brief summary of management practices for irrigated agriculture. Its purpose is to help growers protect ground and surface water supplies in Oregon. Many of these practices also will result in savings of water, energy, and nutrients, to the benefit of the grower. This publication is focused on best management practices, and is supported by a list of relevant reference publications to which the reader can turn for more detailed information.

The publication is derived—much of it verbatim—from an earlier publication by Hermanson and Canessa (1995), which was funded by the Washington Department of Ecology. Their excellent work has been adapted for Oregon in several ways: (1) by adding material derived from research and field experience in Oregon and other states, (2) by supplementing the list of references, and (3) by modifying those sections that deal with statutes particular to the individual states.

This publication is concerned with both point sources and nonpoint sources of water contamination. In irrigated agriculture, important point sources are agrichemical spills or leaks and the back-siphoning of agrichemicals into wells due to improperly used chemigation equipment. Important nonpoint sources include the leaching of nutrients and/or pesticides from the crop root zone and surface runoff. State and federal agencies emphasize **voluntary** adoption

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of practices that will reduce and prevent nonpoint source pollution. This publication is not a regulatory document. However, some practices contained herein are regulated by state law (e.g., chemigation).

We present six management objectives along with corresponding farm practices designed to meet each objective. The six overall management objectives are:

1. Minimize water losses in the on-farm distribution system
2. Improve irrigation system performance and management
3. Manage fertilizer program to minimize excess fertilizer leaching and runoff
4. Manage crop protection programs to minimize leaching and runoff of chemical residues
5. Reduce contamination of surface water by sedimentation
6. Prevent aquifer contamination at wellhead

References

Pertinent standards, engineering practices, Extension publications, rules and statutes, and other references are cited where applicable. These references will help you evaluate and implement a specific practice.

References to ASAE Standards can be found in:

American Society of Agricultural Engineers,
ASAE Standards, 42nd edition (1995)

References to SCS National Practices can be found in:
U.S. Soil Conservation Service
National Engineering Handbook, Section 15 (1983).

A number of statutes listed as OAR-xxx (Oregon Administrative Rules) are available from the Oregon Department of Water Resources.

Other sources are referenced by number. See the corresponding number in "References" (page 24) for complete information.

Many of these references are Extension publications from Oregon State University, Washington State University, and the University of Idaho. See page 34 for ordering information for these publications.

Before considering the adoption of any practices in this publication, develop an overall management goal for the farm. For example, an overall management goal could be to improve on-farm water application efficiency for periods of drought. In this case, most of the management objectives listed above would be applicable. Note that some of the management practices suggested will require on-farm experimentation and/or several years of experience to implement satisfactorily.

Of fundamental importance to proper irrigation water management and overall farm management are proper design and calibration of equipment, equipment maintenance, and careful recordkeeping.

Management Objectives and Practices

OBJECTIVE 1

Minimize water losses in the on-farm distribution system

The on-farm distribution system moves water from the primary supply (well, canal, or river) to the field(s). Depending on configuration, the on-farm distribution system may cause erosion of unlined ditches and deep percolation from seepage.

- 1.1 Install concrete slip-form ditches to replace earthen ditches.
ASAE Standard S289.1
SCS National Practices 320, 437A
- 1.2 Convert earthen ditches to pipelines or gated pipe.
ASAE Standards S376.1, S261.6
SCS National Practices 430-AA through HH
- 1.3 Install flexible membrane linings in earthen ditches and/or reservoirs.
ASAE Standard EP340.2
SCS National Practices 428B, 521A
- 1.4 Install swelling clays or other engineered material in continuously filled earthen ditches and/or reservoirs.
SCS National Practices 521B through E
- 1.5 Maintain ditches and pipelines to prevent leaks.
SCS National Practice 587
Reference 15

OBJECTIVE 2

Improve irrigation system performance and management

Efficient irrigation makes the best use of available water while minimizing the negative effects on water quality from deep percolation and surface runoff. Good irrigation system performance is the result of a carefully considered system design, prudent equipment maintenance, and proper irrigation water management. Knowing when and how much to irrigate is important for effective management. You can accomplish this through irrigation scheduling (see Appendix A).

General recommendations for all system types

- 2.1 Measure all water applications accurately.
SCS Handbook, Section 15, Chapter 5 for siphon tubes
References 84, 84, and 85
- 2.2 Monitor pumping plant efficiency. Consult local utility regarding energy audit programs.
References 15, 17, 44, and 91
- 2.3 Regularly evaluate the irrigation system using standardized procedures.
ASAE Standard S298.1 for sprinkler testing
ASAE Standard EP419 for furrow systems
ASAE Standard S436 for center-pivots
Contact your local NRCS or SWCD office.
Reference 15
- 2.4 Evaluate water quality and soil chemistry to determine required annual leaching ratios to maintain salt balances in the root zone.
SCS National Practice 610
References 13 and 89

- 2.5 Use irrigation scheduling as an aid to decide when and how much to irrigate.
See Appendix A
- 2.6 Consider changing type of irrigation system to improve irrigation performance.
Contact NRCS/SWCD office or irrigation dealership
- 2.7 Use aerial photography (either conventional or, preferably, infrared) to help identify irrigation and/or drainage problems.
Reference 2
- 2.8 Properly design, construct, and maintain subsurface drainage systems to manage water table, if applicable.
ASAE Standards EP463, 470

Practices for surface irrigation (furrow/rill/border)

- 2.9 Improve uniformity by increasing furrow flows to maximum non-erosive stream size during advance. (See also 2.15.)
- 2.10 Employ surge flow techniques (intermittent pulses of irrigation water) to increase uniformity
ASAE Standard EP419
References 34, 39, 64, 65, 70, and 72
- 2.11 Improve uniformity in large fields by decreasing length of furrow runs. This may be accomplished by laying gated pipe through the center of the field.
- 2.12 For improved uniformity, install a suitable field gradient using laser-controlled land grading.
SCS National Practices 464, 466

- 2.13 Equalize furrow infiltration rates by driving a tractor in the uncompacted furrows to intentionally form all “wheel traffic” furrows.
- 2.14 Rip hardpans and compacted soil layers to improve infiltration rates.
SCS National Practice 324
- 2.15 After advance, “cut back” or reduce furrow inflow rates to reduce runoff while ensuring good uniformity.
- 2.16 Install systems to recover and re-use runoff or “tailwater.”
ASAE Standards EP408.1:360.1
SCS National Practice 407
- 2.17 Practice alternate or alternating furrow irrigation.
References 38 and 39
- 2.18 Use polyacrylamide or straw mulching to control erosion. (See 5.3 and 7.2.)

Practices for sprinkle irrigation systems

- 2.19 Have an irrigation engineer or specialist check hand-line and side-roll field layouts to ensure correct combinations of spacing, operating pressure, sprinkler head, and nozzle size/type to ensure proper overlap of sprinkler patterns. Use a lateral offset technique if practical.
References 33 and 78
- 2.20 Have an irrigation engineer or specialist check field layouts for flow uniformity between sprinklers. Use flow control nozzles and pressure regulators as necessary.

- 2.21 Maintain sprinkler systems in good operating condition.
References 15 and 40
- 2.22 Operate in low-wind conditions if possible to avoid excessive drift and evaporative losses.
- 2.23 Ensure that sprinkler packages match the infiltration rate of the soil, especially at the outside edges of a center-pivot. Sprinkler packages should be consistent with topography and soil water-holding capacity.
SCS Handbook, Section 15, Chapter 2
References 14, 29, and 76
- 2.24 Test sprinklers for performance using standardized procedures. Test information should be available from dealer or manufacturer.
ASAE Standards S330.1, S328.1
- 2.25 Minimize surface runoff from sprinkle-irrigated fields. Use reservoir tillage techniques (hammer/diker), conservation tillage techniques, and manage agricultural residues.
Reference 14
- 2.26 For container nurseries, install runoff-reuse or zero runoff systems. Zero discharge is required by ODEQ during the irrigation season, between May 1 and October 1.
Reference 45

Practices for micro-irrigation systems

- 2.27 Have an irrigation engineer or specialist check the design for pressure uniformity. Use pressure/flow regulators and pressure-compensating emitters as necessary.
ASAE Standards EP405.1

- 2.28 Have irrigation water analyzed to properly design water treatment and filtration system. (See also 3.6.)
Reference 68
Contact your irrigation dealership
- 2.29 Test combinations of irrigation water/fertilizer/other additives in the system to ensure compatibility. (See also 3.6.)
- 2.30 Practice regular maintenance to ensure designed system performance.
ASAE Standards EP405.1, EP458.

OBJECTIVE 3

Manage fertilizer program to minimize excess fertilizer leaching and runoff

A well planned and managed fertilizer program is essential to produce crops economically and with minimal contamination of ground and surface water supplies. The nutrients of primary concern are nitrate-nitrogen and phosphorus. Nitrate-nitrogen is susceptible to leaching with deep percolation. In contrast, phosphorus tends to adhere to soil particles and may be lost to surface water bodies when erosion and runoff occur.

Fertigation is the practice of applying nutrients by injecting them directly into the stream of irrigation water. It is an effective and convenient method for applying nutrients. Oregon Administrative Rule OAR 690-215-017 covers the requirements for chemigation/fertigation equipment.

Overall good practices for fertilizer management

- 3.1** Assess the risk of contamination of ground and surface waters.

References 24 and 27

- 3.2** Consider cropping patterns that include deep-rooted crops to scavenge residual fertilizer. Small grains, corn, and sugar beets are deep-rooted crops that might be considered.

Reference 12

- 3.3** Maintain records of all tissue tests, fertilizer tests, cropping rotations, yields, and applications.

- 3.4** Employ a nutrient "budget" to balance crop needs with fertilizer applications. See 3.5 through 3.7.

- 3.5** Analyze fields for residual nutrients prior to planting, occasionally sampling to deeper depths (e.g., 4 to 6 feet) to determine level of nitrogen below the 2-foot level. Then reduce additional nitrogen applied for deeper rooted crops (see 3.2).

Reference 33

- 3.6** Analyze irrigation water for nitrogen content, and if the water contains nitrogen, reduce the amount of additional nitrogen applied proportionately.

References 66 and 88

- 3.7** Analyze plant tissue to identify fertilizer requirements during the growing season.

- 3.8** Estimate nitrogen mineralization rates and use those estimates to adjust fertilizer applications. Contact a local soils testing service for assistance.

- 3.9 Always calibrate application equipment, including manure spreaders, to uniformly apply the planned amount.
- 3.10 Develop realistic yield goals and maintain yield records.
- 3.11 Schedule fertilizer applications to avoid periods when irrigation is being done for purposes of leaching, plant cooling, or frost control.
- 3.12 Use nitrification inhibitors when applying ammonium forms of nitrogen. Nitrate-nitrogen is most susceptible to leaching losses.
- 3.13 Use slow-release nitrogen fertilizers.
- 3.14 Incorporate surface-applied fertilizers immediately to reduce volatilization. This is particularly important for urea and ammonium-based nitrogen fertilizers applied to alkaline soils. Also important for manure.
- 3.15 On sandy, porous soils subject to rapid leaching, avoid applying large amounts of nitrogen at preplant or early-season whenever possible. Apply smaller amounts as needed during the growing season.

Special considerations for manure applications

- 3.16 Test manure or other waste materials for nutrient content, and reduce additional nutrients applied accordingly.
References 19, 21, and 41
- 3.17 Do not apply manure to frozen ground, especially on sloping fields.

**Special considerations for fertigation
(application of fertilizers with irrigation)**

3.18 Analyze irrigation water for compatibility with fertilizer to be applied. Ammonia injection raises pH and possibly causes soluble calcium and magnesium to coat the inside of pipes and to plug emitters. For phosphorus fertilizers, if the water contains appreciable amounts of calcium, any form of phosphorus will precipitate and coat pipelines and emitters. This possibility can be checked by mixing irrigation water and chemicals at application concentrations and normal temperatures and looking for evidence of precipitation.

References 43 and 73

3.19 Use fertigation properly and in accordance with state regulations. In Oregon, OAR 690-203-017 covers requirements for fertigation/chemigation equipment.

ASAE Standard EP409.1

Reference 76

3.20 Design and maintain irrigation system for good application uniformity. See also 2.19–2.21.

ASAE Standard S298.1 for sprinkler testing

ASAE Standard EP419 for furrow systems

ASAE Standard S346 for center-pivots

Contact your local NRCS/SWCD office

References 15 and 40

OBJECTIVE 4 **Manage crop protection program to minimize leaching and runoff of chemical residues**

The primary factors that affect an agrichemical's fate are the pesticide properties (its ability to adhere to soil particles, the rate at which it breaks down, how easily it dissolves, and how much it vaporizes), soil properties, site conditions, and application practices. Applied pesticides may evaporate, be carried off the field attached to soil particles or in solution, be broken down into other substances, or be taken up by plants or insects as intended. The definition of "pesticide residue" is found in Oregon Administrative Rule (OAR) 340-109.

Effective crop protection while limiting chemical leaching and/or runoff requires a management program. A major practice cited below is Integrated Pest Management (IPM) or Integrated Crop Management (ICM). These terms refer to a collection of management practices that reduces the overall dependency upon synthetic chemicals and increases the effectiveness of those that are used. This encompasses such practices as crop rotation, effective scouting for pests and disease, use of natural biocontrols, soil tillage and conditioning, and irrigation management.

Of particular importance to irrigated agriculture is chemigation. Chemigation is the practice of applying chemicals by injecting them directly into the irrigation water. There are special federal and state requirements concerning the proper implementation of chemigation equipment. The EPA and State of Oregon require all pesticide applicators to be registered.

OAR 603-57

Reference 6

For a technical overview of chemigation, see Reference 73.

Overall good practices

- 4.1 Understand the solubility and movement properties of pesticides and fertilizers in the soil in order to assess the risk of contamination of ground and surface water supplies.
References 24 and 27
- 4.2 Practice Integrated Pest Management techniques where applicable. (Contact your county office of the OSU Extension Service.)
- 4.3 Schedule pesticide applications for maximum effectiveness.
- 4.4 Maintain good records of all chemicals purchased, applied, and in storage, as well as field surveys for pest populations.
References 6 and 37
- 4.5 Read and follow all label instructions.
Reference 36
- 4.6 Transport and store chemicals properly.
Reference 36
- 4.7 Load and mix pesticides properly. Record concentrations and rates of individual applications.
Reference 36
- 4.8 Store and dispose of used containers properly. (The Oregon Agricultural Chemicals and Fertilizers Association sponsors a pesticide container recycling program. Contact your dealer or the OACFA.)
- 4.9 Maintain equipment properly to reduce spills or leaks.

- 4.10 Clean equipment properly after use.
References 36, 47, and 76
- 4.11 Calibrate application equipment.
Reference 76

Special considerations for chemigation

- 4.12 Analyze irrigation water for compatibility with chemicals to be applied by chemigation.
- 4.13 Use chemigation safely and according to regulations.
ASAE Standard EP409.1
OAR 690-215-01
Reference 76

OBJECTIVE 5

Reduce contamination of surface water by sedimentation

Surface soil movement from irrigation, wind, or rainfall creates the potential for contamination by sedimentation. Sediment is itself a contaminant, and also can carry chemicals to surface water. It is therefore important to minimize erosion and surface movement (note that practices that reduce movement may increase deep percolation and leaching).

Methods to reduce in-field erosion

- 5.1 Use cover crops on unprotected soils that are easily eroded by wind or water.
- 5.2 Manage crop residues and/or soil stabilizing crops to increase surface roughness and infiltration, and to decrease surface movement by wind erosion.
SCS National Practices 328, 344, 354

- 5.3 Install straw mulch in row-crop furrows. This practice is of particular importance for furrow irrigation of easily erodible soils.

SCS National Practice 484

References 22, 56, 63, and 87

- 5.4 Use reduced tillage, such as paraplow systems.

SCS National Practice 329

- 5.5 Grade the land to optimize field slopes for improved irrigation uniformity and reduced runoff with furrow irrigation systems.

SCS National Practices 464, 466.

- 5.6 Install tailwater drop structures to spread out erosive energy in steeply sloping terrain.

SCS National Practice 416

- 5.7 Install buried tailwater drops and collection pipes.

- 5.8 Properly design, install, and maintain surface drainage systems.

ASAE Standards EP302, EP407

- 5.9 For furrow irrigation of erodible soils, treat irrigation water with polyacrylamide (PAM), a chemical that reduces erosion.

Reference 63

Practices to treat sediment-laden runoff water

- 5.10 Install sedimentation basins.

ASAE Standard S442

SCS National Practice 350

- 5.11 Install vegetative buffering (filter) strips.

SCS National Practice 393

- 5.12 Collect and reuse surface runoff.
ASAE Standards EP408.1, 369.1
SCS National Practice 447
Reference 85

OBJECTIVE 6

**Prevent aquifer
contamination at wellhead**

Wells are a direct link from the surface to ground water. Aquifer contamination can occur because of movement of nutrients or other chemicals from the surface through or along the well. Activities near the wellhead may introduce contaminants to the well; therefore, those activities should be identified and curtailed.

The 1986 amendment to the federal Clean Water Act (CWA) requires each state to develop guidelines for wellhead protection for public water supplies. A wellhead protection area is defined as: "The surface and subsurface area surrounding a water well or wellfield supplying a public water system through which contaminants are likely to move toward and reach such water well or wellfield." The Oregon Department of Environmental Quality (ODEQ) is the lead agency for this program and is responsible for developing educational as well as technical guidelines (references 69 and 85).

Abandoned wells must be properly filled and capped so there is no path from the surface to the aquifer. The Oregon Department of Water Resources (OWRD) is responsible for developing well construction, maintenance, and abandonment requirements. Well construction and abandonment generally are covered by Oregon State law (*ORS 537.505, 537.772, 537.775*) and administrative rule (*OAR 690-220*).

Special considerations for well construction and maintenance

- 6.1 Properly design and construct irrigation wells.
ASAE Standard EP400.1
- 6.2 Construct wells properly where there is the possibility of cascading flows contaminating a lower aquifer.
- 6.3 Identify and properly seal all abandoned and improperly constructed wells.
ORS 537.772, 537.775
Reference 1
- 6.4 Prevent back siphonage/flow of chemicals or nutrients down a well during or after chemigation.
ASAE Standard EP409.1
OAR 690-215-017
Reference 76
- 6.5 Do not store, load, or mix chemicals near a wellhead or other vulnerable place.
Reference 86

Summary

Improved irrigation system hardware and management may result in greater *distribution uniformity* and improve the potential for higher application efficiency. It follows that distribution uniformity is the first concern when improving irrigation system performance.

However, achieving high *application efficiency* ultimately depends on the management of the system, that is, knowing **when** and **how much** to irrigate. Irrigation scheduling techniques greatly enhance the irrigator's ability to manage water applications. Furthermore, it

is necessary to properly maintain irrigation equipment so that system performance is dependable and predictable.

Proper management of fertilizers and agrichemicals will limit their availability for leaching or runoff losses possibly contaminating ground and surface water supplies. Maintaining and calibrating all application equipment and careful record keeping are critical to a good management program.

The application of fertilizers and pesticides through irrigation water (chemigation) can be an effective and efficient mode of application. There are, however, federal and state requirements that must be met when operating chemigation equipment. Irrigators also must consider the role of cultural practices in irrigation performance, nutrient and pesticide management, and soil erosion (especially on sloped fields and on fields susceptible to wind erosion).

Groundwater contamination also may occur at or near a wellhead. Chemicals should not be stored, loaded, or mixed near a wellhead. In addition, wells should be properly constructed, maintained, and, if necessary, abandoned as required by the State Water Resources Department of Oregon.

References

General references

- American Society of Agricultural Engineers, *ASAE Standards*, 42nd ed. (1995).
- U.S. Soil Conservation Service, *National Engineering Handbook*, Section 15: Irrigation (1983).
- Oregon Administrative Rules* (available from the Oregon Department of Water Resources)

Numbered references

1. *Abandoned Wells*, EB 1714 (Washington State University).
2. Baber, J.A., Detecting Crop Conditions with Low-Altitude Aerial Photography. In *Remote Sensing for Resource Management* (Soil Conservation Society of America, 1982).
3. Brown, L., and L. Booher, *Irrigation on Steep Land*, Circular 561 (California Agricultural Experiment Station and Extension Service, 1972).
4. Canessa, P., and R. Hertrich, *Irrigation Management Practices to Protect Groundwater and Surface Water Quality*, EM 4885 (Washington State University, 1995).
5. Cuenca, R., J. Buss, A. Martinez-Cob, G. Katul, and J. M^a Faci González, *Oregon Crop Water Use and Irrigation Requirements*, EM 8530 (Oregon State University, 1992).
6. Environmental Protection Agency, *Code of Federal Regulations*, Volume 40, Part 171, Certification of Pesticide Applicators.

7. Feibert, E., C. Shock, and M. Saunders, A Preliminary Investigation of the Optimum Soil Water Potential for Quality Onion Production. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
8. Feibert, E., C. Shock, and M. Saunders, A Preliminary Comparison of Sprinkler, Subsurface Drip and Furrow Irrigation of Onions. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
9. Feibert, E., C. Shock, and M. Saunders, A Comparison of Sprinkler, Subsurface Drip and Furrow Irrigation of Onions. In *Malheur County Crop Research Annual Report, 1994* SR 947 (Oregon State University, 1995).
10. Feibert, E., C. Shock, and M. Saunders, Appropriate Nitrogen Fertilization for Potato Varieties Grown in the Treasure Valley. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
11. Feibert, E., C. Shock, and M. Saunders, Nitrogen Fertilization for Potato Varieties Grown Under Sprinkler Irrigation, 1994 Trial. In *Malheur County Crop Research Annual Report, 1994*, SR 947 (Oregon State University, 1995).
12. Pollett, F., D. Kenney, and R. Cruse, *Managing Nitrogen for Groundwater Quality and Farm Profitability* (Soil Science Society of America, Inc., Madison, WI, 1991).
13. Gardner, H., and J. Hart, *How to Take a Soil Sample. . .and Why* EC 628 (Oregon State University, revised 1995).
14. Hansen, H., and W. Trimmer, *Irrigation Runoff Control Strategies*, PNW 287 (Oregon State University, 1986).
15. Hansen, H., and W. Trimmer, *Irrigation System Walk-Through Inspection Analysis*, PNW 293 (Oregon State University, 1986).

References

16. Hansen, H., and W. Trimmer, *Converting Sprinkler Systems to Lower Pressure*, PNW 289 (Oregon State University, 1986).
17. Hansen, H., and W. Trimmer, *Pumping Plant Efficiencies*, PNW 285 (Oregon State University, 1986).
18. Hart, J. *A List of Analytical Laboratories Serving Oregon*, FG 74 (Oregon State University, revised 1996).
19. Hart, J., M. Gangwer, M. Graham, and E. Marx, *Dairy Manure as a Fertilizer Source*, EM 8586 (Oregon State University, reprinted 1996).
20. Hermanson, R., and P. Canessa, *A Ready Reference for Irrigation Manual of Practice*, EB 1810 (Washington State University, 1995).
21. Hermanson, R., and P. Balita, *Animal Manure Data Sheet*, EB 1719 (Washington State University, 1994).
22. Hobson, J., L. Jensen, K. Langley, G. Shock, T. Stieber, M. Thornton, and T. Jensen, *Mechanical Straw Mulching and Reservoir Tillage Effects on Shepody Potatoes in the Treasure Valley*, In *Malheur County Crop Research Annual Report, 1993*, SR 936 (Oregon State University, 1994).
23. *Home-Ac-Syst Homestead Assessment System*, EM 8546 (Oregon State University, 1993).
24. Huddleston, J., *How Soil Properties Affect Groundwater Vulnerability to Pesticide Contamination*, EM 8559 (Oregon State University, 1994).
25. Jensen, M., R. Burman, and R. Allen, eds., *Evapotranspiration and Irrigation Water Requirements*, American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 70 (ASCE, New York, 1990).

26. Keller, J., and R. Bliesner, *Sprinkle and Trickle Irrigation* (Chapman and Hall, 1990).
27. Kerle, E., J. Jenkins, and P. Vogue, *Understanding Pesticide Persistence and Mobility for Groundwater and Surface Water Protection*, EM 8561 (Oregon State University, reprinted 1994).
28. Kerle, E., P. Vogue, J. Jenkins, and J. Huddleston, *Site Assessment for Groundwater Vulnerability to Pesticide Contamination*, EM 8560 (Oregon State University, 1994).
29. Kranz, W., Matching Sprinkler Packages with Field Conditions, *Irrigation Journal* (November/December 1995).
30. Lenhart, N., and M. Sward, *The State of Water in Oregon*, EC 1426 (Oregon State University, 1993).
31. Ley, T., R. Stevens, R. Topiclec, and W. Weibling, *Soil Water Monitoring and Measurement*, PNW 475 (Oregon State University, 1994).
32. Ley, T. *Simple Irrigation Scheduling Using Pan Evaporation*, EB 1604 (Washington State University, 1984).
33. Ley, T., Set/Move and Permanent Sprinkler Irrigation Systems, *Irrigation Journal* (November/December 1995), pp. 30-32.
34. Miller, J., and C. Shock, The Effect of Surge Irrigation on Onion Yield and Quality, Irrigation Efficiency, and Soil Nitrogen Losses. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
35. Miller, J., C. Shock, and M. Saunders, Efficiency of Nitrogen Fertilization on Onions. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
36. Miller, T., *Oregon Pesticide Applicator Manual*, EM 8532 (Oregon State University, reprinted 1994).

References

37. Miller, T., *Pesticide Application Record* (Oregon State University, 1993).
38. Mitchell, A., J. Light, and T. Page, Alternate and Alternating Furrow Irrigation to Minimize Nitrate Leaching. In *Central Oregon Agricultural Research Center Annual Report, 1990–1992*, SR 922 (Oregon State University, 1993).
39. Mitchell, A., and K. Stephenson, Surge Flow and Alternating Furrow Irrigation of Peppermint to Conserve Water. In *Central Oregon Agricultural Research Center Annual Report, 1993*, SR 930 (Oregon State University, 1994).
40. Montana Department of Natural Resources and Conservation, *Irrigator's Pocket Guide* (Oregon State University Energy Extension, undated).
41. Moore, J., and M. Garroth, *Calculating the Fertilizer Value of Manure from Livestock Operations*, EC 1094 (Oregon State University, reprinted 1993).
42. Moore, J., and T. Willich, *Manure Management Practices to Reduce Water Pollution*, FS 291 (Oregon State University, reprinted 1993).
43. Nakayama, F., *Water Analysis and Treatment Techniques to Control Emmitter Plugging*. Water, Energy and Economic Alternatives, pp. 97–112, 1982 Annual Technical Conference Proceedings, Feb. 21–24, Portland, OR (The Irrigation Association).
44. New, D., and B. Neal. Pumping Plant Efficiency Tests, *Irrigation Journal* (July/August 1995).
45. *Oregon Container Nursery Irrigation Water Management Plan* (Oregon Department of Agriculture, 1991).

46. Oregon Department of Energy, *Oregon Business Energy Tax Credit (BETC), Application for Preliminary Certification—Conservation Projects* (1993).
47. Oregon Department of Environmental Quality, *Oregon Waste Reduction Assistance Program*, Factsheet (1993).
48. Oregon Department of Environmental Quality, *Groundwater Management and Protection Strategy: Oregon Plan* (July 1983).
49. Oregon Department of Environmental Quality, *Oregon's 1994 Water Quality Status Assessment Report, 305(b)* (April 1994).
50. Oregon Water Resources Department, *1993 Oregon Water Laws*, Volume 1 (1993).
51. Oregon Water Resources Department, *1993 Oregon Water Laws*, Volume II (1993).
52. Parsons, D., and J. Witt, *Pesticides in Groundwater in the United States of America*, EM 8406 (Oregon State University, 1989).
53. *Pesticide Application Records* (Oregon Department of Agriculture, undated).
54. Reaves, R. Going with the Flow: A Look at Flowmeters, *Irrigation Journal* (September/October 1995).
55. Shock, C. M., Barnum, and A. Mitchell, Alternate and Alternating Furrow Irrigation of Small Grain as Low Cost Options to Improve Irrigation Efficiency and Reduce Nitrate Leaching. In *Malheur County Crop Research Annual Report, 1993*, SR 936 (Oregon State University, 1994).

References

56. Shock, C., J. Hobson, J. Banner, L. Saunders, and T. Stieber, An Evaluation of Mechanically Applied Straw Mulch on Furrow Irrigated Onions. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
57. Shock, C., E. Feibert, and M. Saunders, Appropriate Irrigation Management for Potato Varieties; Variety Tolerance to Deficit Irrigation. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1992).
58. Shock, C., T. Stieber, and E. Eldredge, A Comparison of Drip, Sprinkler, and Furrow Irrigation of Potatoes. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
59. Shock, C., J. Hobson, J. Banner, L. Saunders, and B. Townley, Improved Irrigation Efficiency and Erosion Protection by Mechanical Furrow Mulching Sugarbeets. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
60. Shock, C., T. Stieber, and J. Miller, Nutrient Content in Northeastern Malheur County Irrigation Water. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
61. Shock, C., E. Feibert, and M. Saunders, Soil Water Potential Criteria for Onion Irrigation, 1994 Trial. In *Malheur County Crop Research Annual Report, 1994*, SR 947 (Oregon State University, 1995).
62. Shock, C., E. Feibert, and L. Saunders, Irrigation Management for Potato Varieties; Variety Tolerance to Deficit Irrigation. In *Malheur County Crop Research Annual Report, 1994*, SR 947 (Oregon State University, 1995).

63. Shock, C., J. Zattiero, K. Kantola, and M. Saunders, Comparative Cost and Effectiveness of Polyacrylamide and Straw Mulch on Sediment Loss from Furrow Irrigated Potatoes. In *Malheur County Crop Research Annual Report, 1994*, SR 947 (Oregon State University, 1995).
64. Shock, C., L. Saunders, M. English, R. Mittelstadt, and B. Shock, Surge Irrigation of Wheat to Increase Irrigation Efficiency and Reduce Sediment Loss, 1993. In *Malheur County Crop Research Annual Report, 1993*, SR 936 (Oregon State University, 1994).
65. Shock, C., L. Saunders, M. English, R. Mittelstadt, and B. Shock, Water Savings Through Surge Irrigation, 1994. In *Malheur County Crop Research Annual Report, 1994*, SR 947 (Oregon State University, 1995).
66. Shock, C., T. Stieser, and J. Miller. Nutrient Content in Northeastern Malheur County Irrigation Water. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
67. Simko, P., and L. Jensen. Survey for Pesticide Residues in Malheur County Surface Water. In *Malheur County Crop Research Annual Report, 1992*, SR 924 (Oregon State University, 1993).
68. Srinivastula, A. Causes and Prevention of Emitter Clogging in Micro-irrigation Systems, *Irrigation Journal* (April 1995).
69. Stewart, S., and D. Nelson, *Oregon Wellhead Protection Program Guidance Manual* (Oregon Department of Environmental Quality and Oregon Health Division, Review Draft, 1995).

References

70. Stringham, G. (editor), *Surge Flow Irrigation, Final Report of the Western Regional Research Project W-163*, Research Bulletin 515 (Utah State University, 1988).
71. Sullivan, D., *Biosolids Recycling in Oregon*, EC 1471 (Oregon State University, 1996).
72. Surge: The Cutting Edge of Irrigation Technology, *Irrigation Journal* (March 1995), anonymous.
73. Threadgill, E., D. Eisenhauer, J. Young, and B. Bar-Yosef. Chemigation. In *Management of Farm Irrigation Systems*, G. Hoffman, T. Howell, and K. Solomon, eds. (ASAE Monograph, 1990).
74. Topielec, R., *Measuring Crop Water Use and Available Soil Moisture*, Energy Note 4306 (Oregon State University, 1993).
75. Trimmer, W., and H. Hansen, *Irrigation Scheduling*, PNW 288 (Oregon State University, reprinted 1994).
76. Trimmer, W., T. Ley, G. Clough, and D. Larsen, *Chemigation in the Pacific Northwest*, PNW 360 (Oregon State University, 1993).
77. Trimmer, W., *Measuring Well Water Levels*, EC 1368 (Oregon State University, reprinted 1994).
78. Trimmer, W., and H. Hansen, *Offsets for Stationary Sprinkler Systems*, PNW 286 (Oregon State University, 1986).
79. Trimmer, W., and H. Hansen, *Electrical Demand Charges—How to Keep Them Low*, PNW 291 (Oregon State University, 1986).
80. Trimmer, W., and H. Hansen, *Extending Electrical Motor Life*, PNW 292 (Oregon State University, 1986).
81. Trimmer, W., and H. Hansen, *Sizing Irrigation Mainlines and Fittings*, PNW 290 (Oregon State University, 1986).

-
82. Trimmer, W., *Stretching Irrigation Water Supplies*, PNW 323 (Oregon State University, revised 1994).
 83. Trimmer, W., and H. Hansen, *Irrigation Scheduling*, PNW 288 (Oregon State University, reprinted 1994).
 84. Trimmer, W., *Estimating Water Flow Rates*, EC 4369 (Oregon State University, reprinted 1994).
 85. Trout, T., *Installation and Use of Powlus V-notch Flumes* (U.S. Agricultural Research Service, Kimberly, ID, undated).
 86. U.S. Environmental Protection Agency, Seminar Publication, *Wellhead Protection: A Guide for Small Communities*, EPA/625/R-93/002 (February 1993).
 87. Uhlig, B., A. Mitchell, and J. Ickler, *Straw Mulch Application to Furrow Irrigated Carrots*. In *General Oregon Agricultural Research Center Annual Report, 1990-1992*, SR 922 (Oregon State University, 1993).
 88. Vomocil, J., and J. Hart, *Rural Domestic Water Supply*, EC 1374 (Oregon State University, reprinted 1992).
 89. Vomocil, J., and J. Hart, *Fertilizer Guide: Irrigation Water Quality*, FG 76 (Oregon State University, reprinted 1992).
 90. Water Resources Commission, *1993-1995 Biennial Water Management Program for Oregon* (January 1993).
 91. Wright, R., M. Nelson, and T. Ley, *Irrigation Pump Efficiency Test*, Energy Note A303 (Oregon State University, 1986).
 92. Wright, R., *Maintaining Impact Sprinklers*, Energy Note A304 (Oregon State University, 1986).
 93. Wright, R., *Checking Electric Motor Load*, Energy Note A305 (Oregon State University, 1986).
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Central Oregon Agricultural Research Center
Main Office, Madras Farm
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Madras, OR 97741

- SR 922 *Central Oregon Agricultural Research Center Annual
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Appendix A. Irrigation Scheduling

An irrigation scheduling program consists of four elements: (1) knowledge of the soils and crop, (2) a method of measuring soil moisture status, (3) a means of measuring or estimating daily crop water use, and (4) an estimate of the application efficiency of your irrigation system. With this information, a water balance (or budget) may be established for a given field, and you will be able to apply the correct amount of water at the right time.

The soil and crop information required are: soil water holding capacity, mature crop rooting depth or root zone depth, and allowable depletion (the percent of water stored in the root zone that is allowed to deplete before irrigation is required). This information may be determined from field experience and/or obtained from other sources including, but not limited to references 31, 32, 40, 74, and 83; the *SCS Engineering Handbook*, Section 15, Chapter 2; or your OSU Extension agent.

An accurate yet economical means of measuring soil moisture in the crop root zone is essential. To help irrigators decide on the appropriate equipment, a recent Pacific Northwest Extension publication, PNW 475 (reference 31), reviews and compares several tools for measuring and monitoring soil moisture.

There are several means by which daily crop water use (evapotranspiration or ET) can be estimated or measured. For evaporation measurement on the farm, a standardized evaporation pan is used, and daily evaporation is related to crop ET by the crop coefficient (reference 32).

Secondly, weather data may be used to calculate daily crop ET by the Modified Penman or Blaney-Criddle methods. An OSU Extension publication, EM 8530 (reference 5), published in 1992, provides monthly estimates of crop water use and irrigation requirements in Oregon for each region and crop. These estimates were calculated using the Modified Blaney-Criddle method along with weather data compiled from 244 existing National Weather Service stations in Oregon.

In addition, several automatic weather stations have been installed throughout Oregon by the U.S. Bureau of Reclamation and Bonneville Power Administration, which collect weather data and transmit the data via satellite to Boise, Idaho, where daily ET is calculated for all important regional crops. This system is known as Agrimet. Current Oregon Agrimet station locations include: Forest Grove, Corvallis, Bandon, Medford, Madras, Hood River, Christmas Valley, Lakeview, Ontario, Prairie City, Echo, Hermiston Research and Experiment Station, and Hermiston (Boardman). Your OSU Extension agent or local experiment station can be of assistance in supplying further information. Or contact the U.S. Bureau of Reclamation Conservation Program Manager in Boise, Idaho.

In general, the application efficiency of an irrigation system depends on the type of system. Application efficiency results from the amount of control the irrigator has over the ultimate distribution of water. It follows that surface irrigation systems generally are less efficient than sprinkle and drip irrigation systems.

Several publications are available that give an estimate of application efficiencies for different system types (reference 83, *SCS National Engineering Handbook*, Section 15, Chapter 2). Equipment design and maintenance and water management also play an important part in application efficiency and cannot be neglected. See Appendix B for definitions of *application efficiency* and *distribution uniformity*.

Appendix B. Irrigation Performance Measures

There are various means of numerically describing irrigation performance. Two of these are *application efficiency* (E_a) and *distribution uniformity* (DU).

Application efficiency is defined as the ratio of the volume of irrigation water beneficially used to the volume of irrigation water applied. Beneficial uses include supplying water to crops, cooling, frost protection, and leaching to control salinity in the root zone.

Distribution uniformity is a measure of how evenly water infiltrates the ground across a field during irrigation. It is expressed as a percentage between 0 and 100 and is defined as the ratio of the average depth of infiltration in the quarter of the field that receives the least water to the average depth of infiltration for the whole field. Good distribution uniformity is essential for reducing deep percolation if the entire field is to be watered sufficiently.

Appendix C. Glossary of Terms

- Aquifer** A geological formation capable of yielding usable quantities of water to wells or springs.
- Application efficiency** (Ea) A measure of how much of the water applied to a field during an irrigation is beneficially used. Beneficial uses include crop evapotranspiration (ET), frost control, leaching for salt control, and cooling. See Appendix B.
- Best management practices** (BMP) A generic term referring to schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of ground or surface water.
- Calibrate** To check and adjust application equipment so that the desired application rate is achieved.
- Cascading flows** Movement of water from a high aquifer to a lower aquifer through well boreholes.
- Chemigation** The application of formulated liquids or solutions of pesticides, herbicides, fungicides, fertilizers, or other agents through the irrigation system.
- Clean Water Act** (CWA) A federal enactment (1972) seeking to maintain the chemical, physical, and biological integrity of the nation's waters. Administrative authority is given to the U.S. Environmental Protection Agency (EPA), and requirements are carried out by the Oregon Department of Environmental Quality. Section 319 covers nonpoint source pollution.

- Cutback irrigation** Reducing the inflow rate of irrigated furrows after the completion of advance.
- Deep percolation** The movement of soil water past the crop root zone.
- Distribution uniformity** (DU) A measure of how evenly water is applied/infiltrated in a field during an irrigation.
- Evapotranspiration** (ET) The sum total of plant transpiration and soil surface evaporation in a cropped field.
- Fertigation** The application of fertilizers through the irrigation system.
- Flume** A flow measurement structure for use with open channels.
- Integrated pest management (IPM)** A combination of pesticide and non-pesticide methods to control pests. Methods include cultural practices, use of biological, physical, and genetic control agents; and the selective use of pesticides.
- Irrigation scheduling** A generic term used to describe a family of methods/techniques that aids a farmer in deciding when to irrigate and how much water to apply.
- Leaching** The movement of chemicals through soil with water.
- Nonpoint source** (NPS) Pollution caused by diffuse sources that are not regulated as a point pollution source.
- OACFA** Oregon Agricultural Chemical and Fertilizer Association.

Polyacrylamide (PAM)	A synthetic chemical that can be applied with irrigation water to reduce erosion by increasing soil cohesion and causing sediments to clump loosely together.
Root zone	The effective depth of crop roots in the soil from which water is extracted.
Soil stabilizing crops	Crops planted specifically to reduce movement of surface soils due to wind or water erosion.
Surge-flow	A technique employed with furrow irrigation to increase uniformity and to reduce runoff by intermittently introducing pulses of irrigation water into a furrow.
SWCD	Soil Water Conservation District.
Tailwater	Irrigation runoff from surface-irrigated fields.
Wellhead	The surface and sub-surface area surrounding a water well or wellfield supplying a public water system through which contaminants are likely to move toward and reach such water well or wellfield.

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10507 N. McAlister Rd.
La Grande, OR 97850
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Others

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Chairman of Containers Recycling Program
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Oregon Agricultural Chemicals and Fertilizers Association
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Oregon Water Resources Department
3850 Portland Road NE
Salem, OR 97310
541-378-3741

University of Idaho Cooperative Extension System
Moscow, ID 83843
208-885-6639

U.S. Bureau of Reclamation
Conservation Program Manager
1150 N. Curtis Rd.
Boise, ID 83706-1234
208-378-5280

U.S. Environmental Protection Agency
Region 10
1300 Sixth Ave.
Seattle, WA 98101
206-553-1200

U.S. Natural Resource Conservation Service (formerly
Soil Conservation Service). NRCS assistance is accessed
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