Imagine the result

George DeRuyter & Son Dairy, LLC

Irrigation Water Management Plan

Administrative Order on Consent

SDWA-10-2013-0080

June 17, 2013

Irrigation Water Management Plan

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Date:
June 17, 2013

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1. Introduction

The following irrigation water management plan was prepared for George DeRuyter & Son Dairy, LLC by Mr. Scott Stephens of AGRIMANAGEMENT, Inc. of Yakima, Washington and ARCADIS U.S., Inc. of Liberty Lake, Washington.

2. Objectives

The objective of Irrigation Water Management (IWM) is to control the volume, frequency, and rate of water applied for efficient irrigation including the following purposes:

- Promote desired crop response and vegetative growth.
- Optimize the use of available water supplied.
- Improve water quality, by reducing irrigation sources of surface and ground water contamination.
- Minimize irrigation induced soil erosion.
- Manage salts in the root zone.
- Improve air quality, by reducing movement of particulate matter.
- Provide appropriate and safe fertigation and chemigation.
- Reduce energy consumption.

3. Components/Criteria

3.1 Farm and field information

List of Sampling Units (SU) with the following information

- Soil series and related water holding capacities (WHC) and infiltration rates.
- Irrigation system type(s)
- Irrigation system specifics (nozzle size; output; etc.)

Map with soils and topography

3.2 Documentation of the scientific method used for scheduling water applications

A Water Balance Method will be used which contains the following components:

- Measurement of stored soil water.
- Measurement of the water withdrawals from the soil, plant system

- Measurement of the applied water as irrigation or rain.

3.3 Method to measure stored soil water

3.3.1 Equipment

1. Decagon Devices Ech2o data loggers (with 5 ports), capacitance sensors, electronic rain gauge and a manual rain gauge.
2. 4' open face soil probe (as a backup in case of possible short-term equipment failure) for verification of soil moisture and for calibration of sensors.
3. Auger or post-hole digger or shovel for digging a hole for sensor installation.

3.3.2 Equipment installation

1. Sensor location will be documented with GPS coordinates
2. Installation area should be located in typical soils and topography to best represent the majority of the field.
3. Auger or dig a hole to 36" depth or to the depth of hardpan or rock.
4. Label and install sensors within the soil profile using a tape measure to define depth as follows:
   - Port 1 = 12" depth
   - Port 2 = 24" depth
   - Port 3 = 36" depth
   - Port 4 = extra
   - Port 5 = Rain gauge (tipping).
5. Install sensors into the undisturbed sidewall of the hole, back-fill, tamp, and return the soil surface as near to the original state as possible.
6. Place post or pvc pipe at least 5' from the sensors and mount both the logger and rain gauge. Connect the labeled sensors into the appropriate port.
7. Set logger firmware to record data on an hourly basis.

3.3.3 Equipment calibration

1. Measure or calculate soil bulk density (BD) for each field and soil depth by collecting soil from depths of 1', 2', and 3' as near as possible to the sensors without altering their function.
2. Use bulk density to calculate % Available water (AW) for each depth from % Volumetric water content (VWC). Percent VWC is the values recorded by the capacitance sensors.
3. Use bulk density to calculate soil field capacity (FC) for each depth. This will help to define a specific level where saturation is reached.

3.4 Method to measure soil water withdrawals (Crop Use + Evaporation)

The Outlook, Wa. AgWeatherNet weather station will be utilized to document and project crop water use through the use of the following:

- Reference Evapotranspiration rates (Et_a)-Alflafa
- Crop Coefficients that correspond to specific physiological stages (K_c)
- ET_c (crop specific evapotranspiration rates) will be calculated weekly for each crop and each crop stage ($ET_c = ET_a \times Kc$)

3.5 Method to measure water applications

1. Flow meters on delivery pipes and/or pivots can be used to measure total water applied (gross)
2. Rain gauges within the field can be used to measure net water applied, including rain events.

3.6 Reporting IWM information

Logged data will be presented in a graphical form that shows the past 1-2 weeks of data with hourly data points on a weekly basis. The report will also show projected ET_c for the next week, crop effective root depth (ERD), inches of depletion or surplus within the root zone and profile and a detailed recommendation for the amount of irrigation water to apply over the next week.

3.7 Irrigation system uniformity estimation/calculation.

If the system uniformity is suspect, then a calculation of uniformity should be made through the use of a rain gauge grid evaluation. Normal operation and maintenance of the plan will need to be done on an annual basis as needed.

4. References

NRCS Conservation Practice Specification, Irrigation Water Management, Code 449

NRCS Conservation Practice Standard, Irrigation System, Sprinkler, Code 442

NRCS Conservation Practice Standard, Irrigation System, Surface and Subsurface, Code 443

NRCS Conservation Practice Standard, Irrigation System, Tailwater Recovery, Code 447

USDA –Soil Conservation Service, National Engineering Handbook, Sec. 15, Irrigation, Soil-Plant-Water Relationships

Tables

Table 1
Application Field Summary Table
Cow Palace, Yakima County, Washington

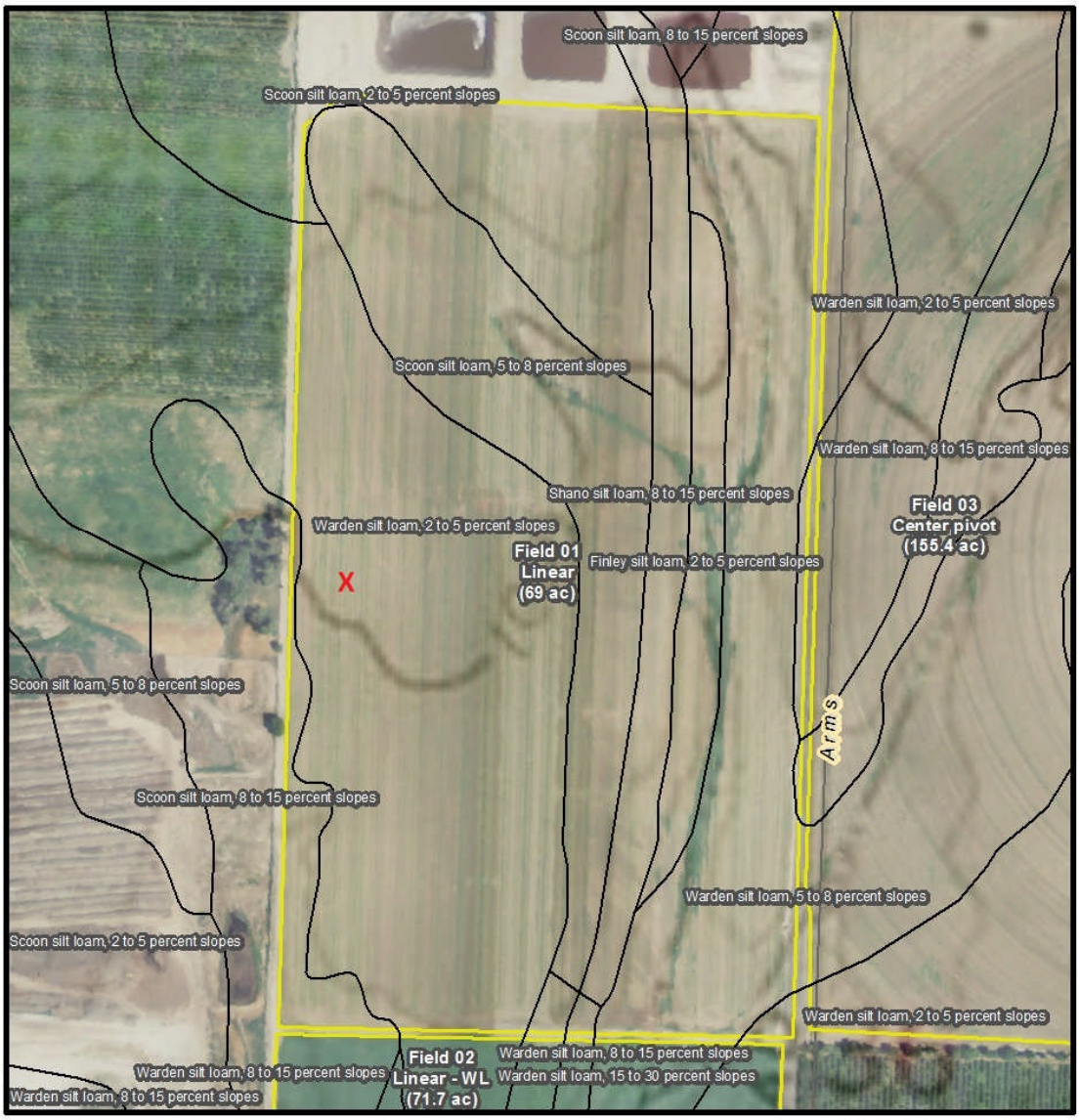
Sampling Unit Designation	Related Application Field	Size (Acres)	Irrigation Type	Soil Series *	AWHC (in/ft)	Infiltration Rate	
						Furrow I'f	Sprinkler I'f
CP-SU-1	Application Field 1	69	Linear	Warden silt loam	2.28	0.29	0.3
CP-SU-2	Application Field 2	71.7	Linear - Wheel line	Warden silt loam	2.28	0.29	0.3
CP-SU-3	Application Field 3	155.4	Center pivot	Warden silt loam	2.28	0.29	0.3
CP-SU-4A	Application Field 4A	71	Wheel line - Rill	Warden silt loam	2.28	0.29	0.3
CP-SU-4B	Application Field 4B	40.1	Wheel line	Warden silt loam	2.28	0.29	0.3
CP-SU-5	Application Field 5	37.1	Wheel line	Warden silt loam	2.28	0.29	0.3
CP-SU-6	Application Field 6	85	Rill - Wheel line	Warden silt loam	2.28	0.29	0.3

Notes
Soil Series* = Only the predominant soil series is listed.
AHWC = Available Water Holding Capacity
Furrow I'f = intake rate in inches per foot for furrow irrigation
Sprinkler I'f = intake rate in inches per foot for sprinkler irrigation

Figures

Cow Palace
Field 01
Linear

N



Agrimanagement, Inc.

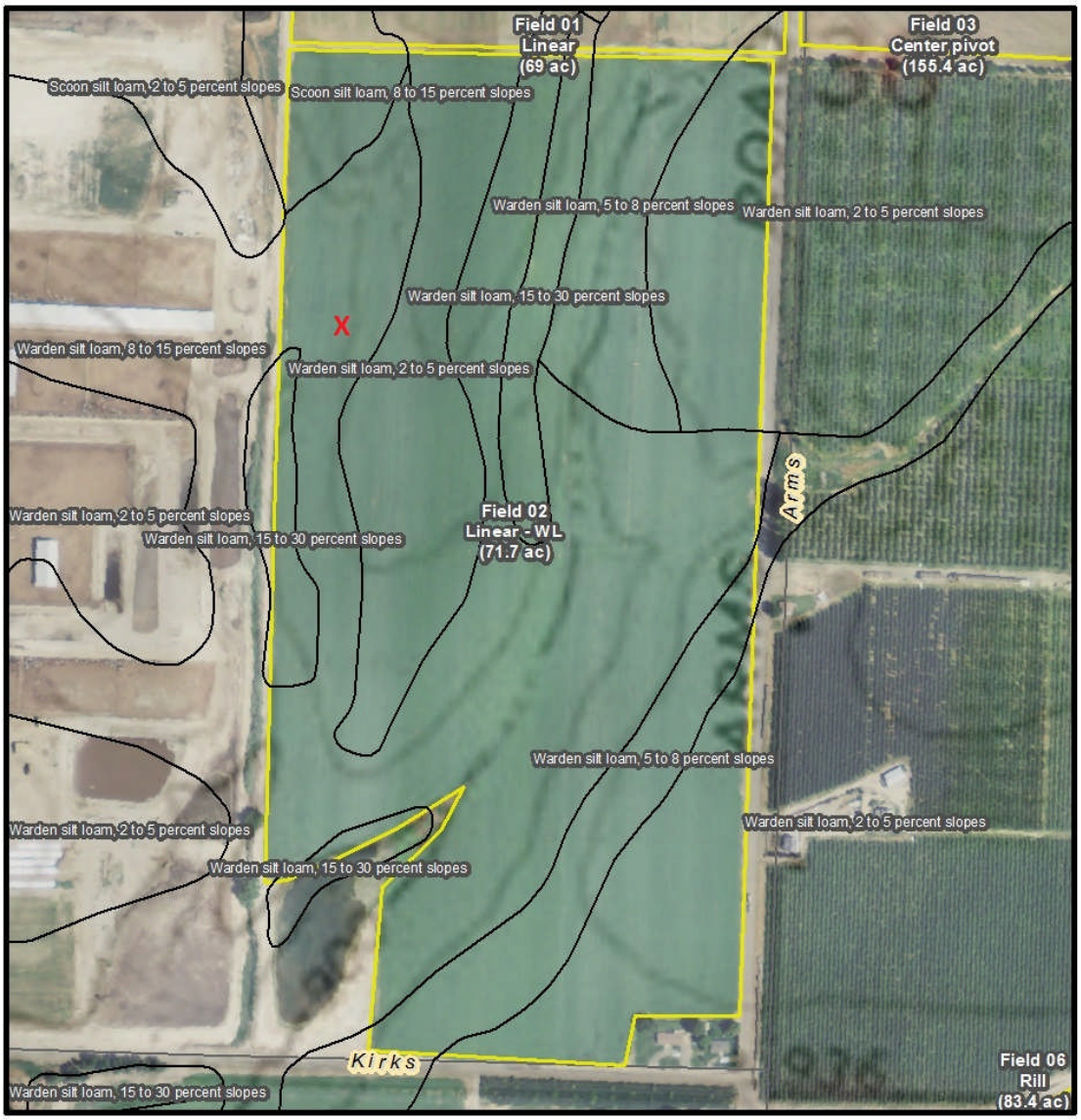
X = Proposed monitoring station

Miles
0 0.02 0.04 0.08

4/29/2013

Cow Palace
Field 02
Linear - Wheel line

N



Agrimanagement, Inc.

Miles
0 0.02 0.04 0.08

X = Proposed monitoring station

4/29/2013

Cow Palace
Field 03
Center pivot

N

Agrimanagement, Inc.

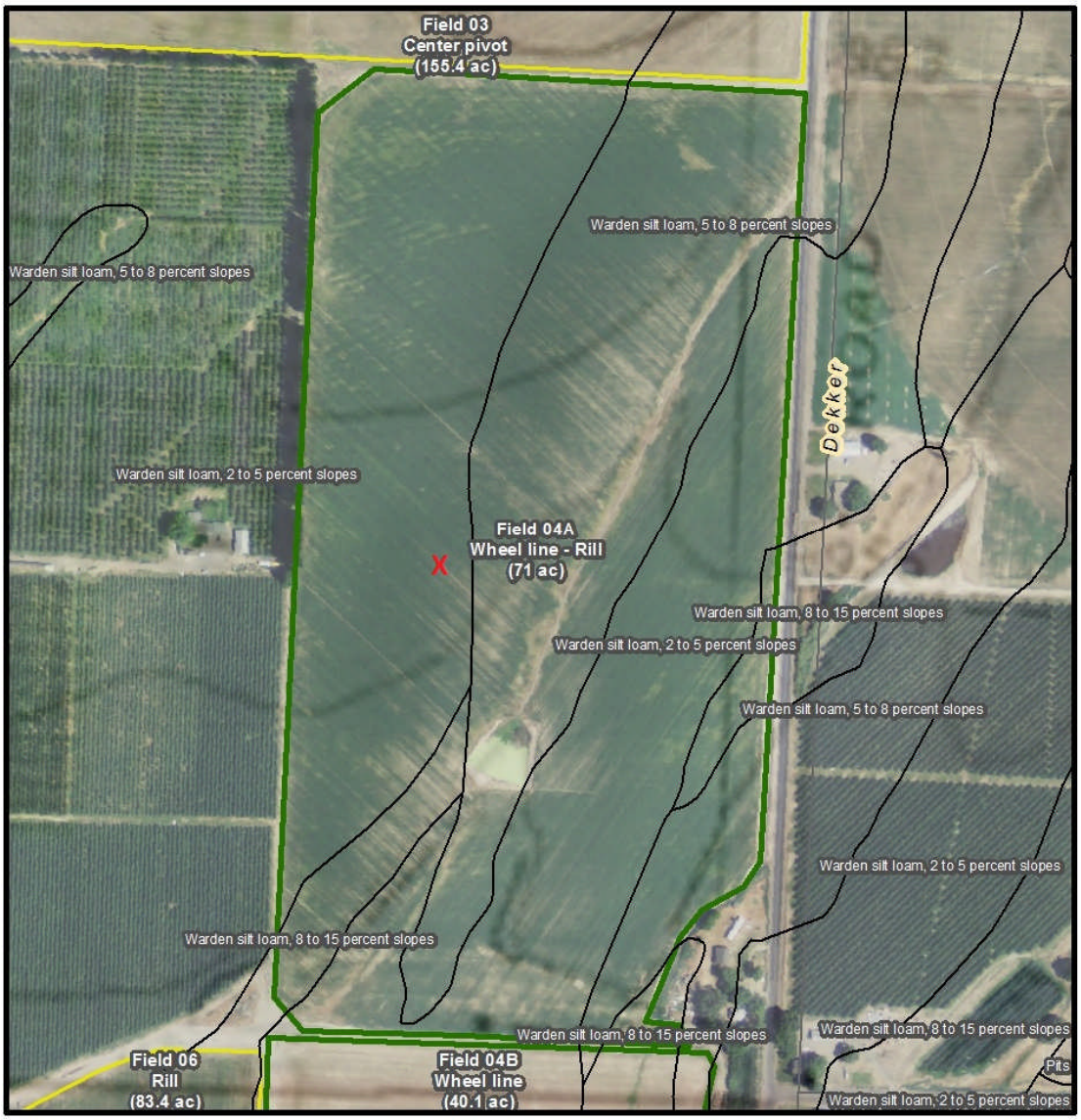
Miles
0 0.020.04 0.08

X = Proposed monitoring station

4/29/2013

Cow Palace
Field 04A
Wheel line - Rill

N



Agrimanagement, Inc.

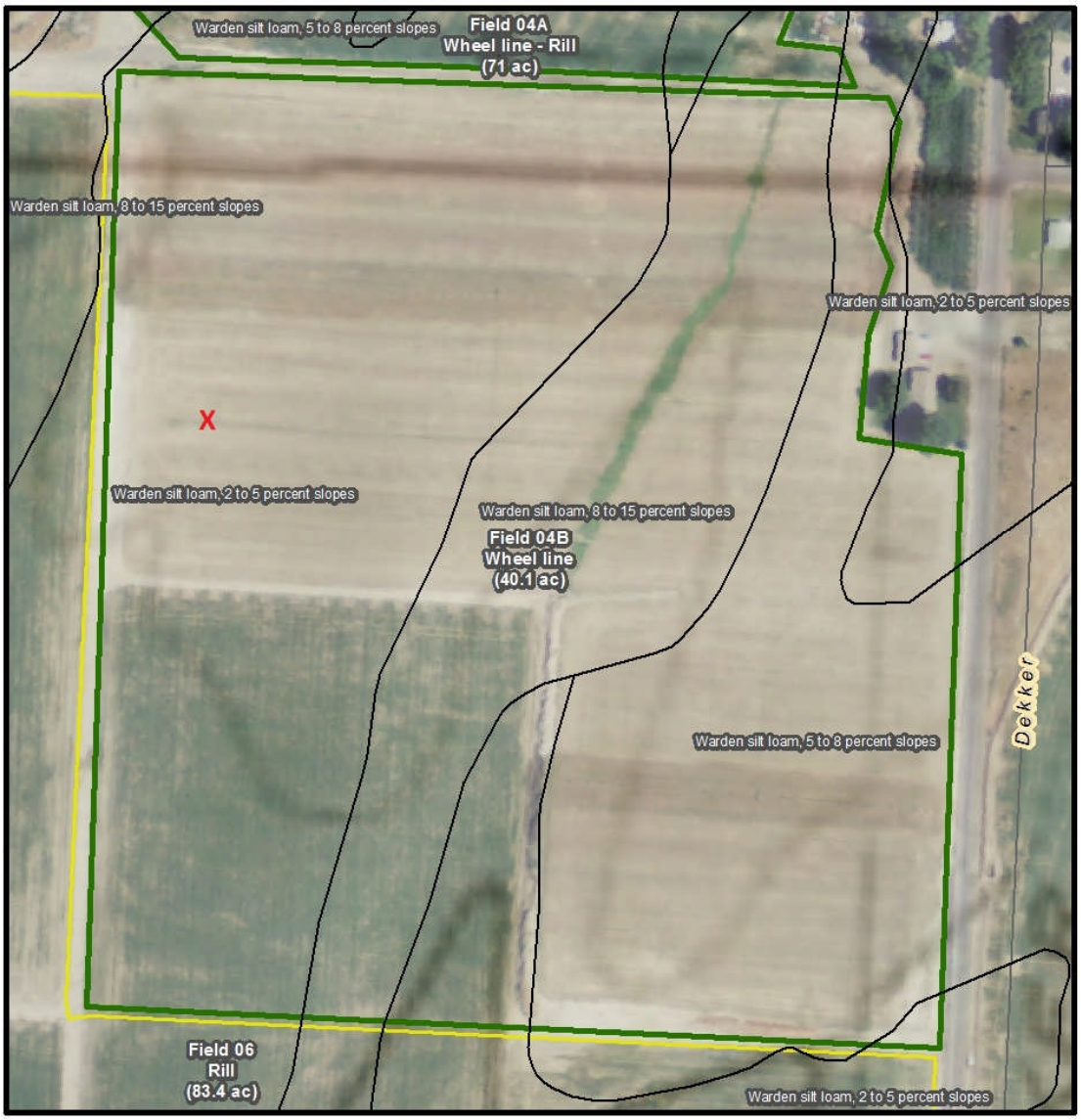
Miles
0 0.02 0.04 0.08

X = Proposed monitoring station

4/29/2013

Cow Palace
Field 04B
Wheel line

N



Agrimanagement, Inc.

0 0.0125 0.025 0.05 Miles

X = Proposed monitoring station

4/29/2013

Cow Palace
Field 05
Wheel line

N

Agrimanagement, Inc.

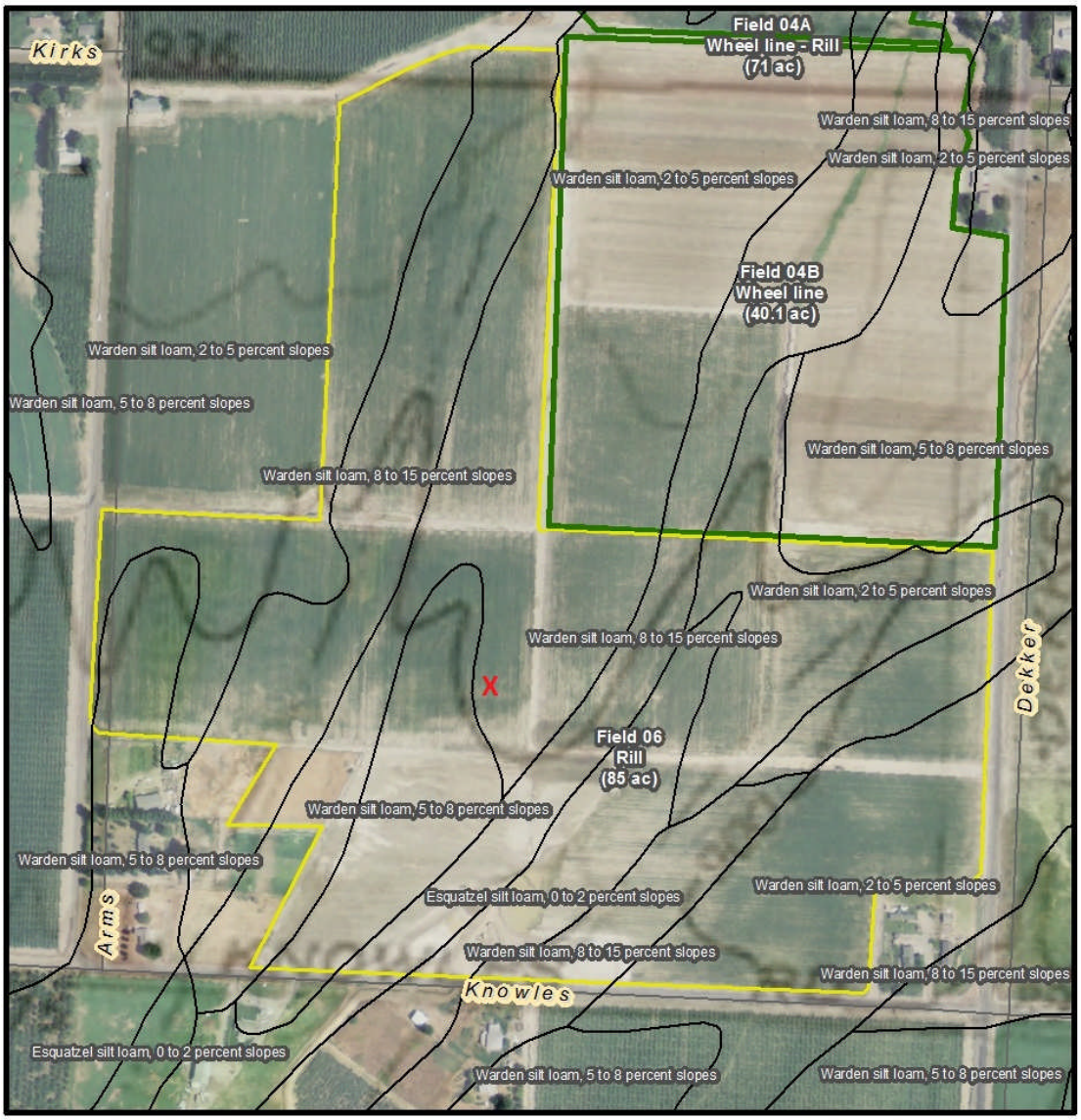
0 0.0125 0.025 0.05 Miles

X = Proposed monitoring station

4/29/2013

Cow Palace
Field 06
Rill

N



Agrimanagement, Inc.

Miles
0 0.020.04 0.08

X = Proposed monitoring station

4/30/2013

Appendix A

Agrimanagement Irrigation Water Management Plan

AGRIMANAGEMENT® INC.
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http://www.agrimgt.com

AGRIMETRIC SERVICES – MEASURING CROP NEEDS FOR GREATER PROFITS

Irrigation Water Management Plan

Administrative Order on Consent

SDWA-10-2013-0080

I. Definition/Objective

The objective of Irrigation Water Management (IWM) is to control the volume, frequency, and rate of water applied for efficient irrigation including the following purposes:

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- Minimize irrigation induced soil erosion.
- Manage salts in the root zone.
- Improve air quality, by reducing movement of particulate matter.
- Provide appropriate and safe fertigation and chemigation.
- Reduce energy consumption.

II. Components/Criteria

a. Farm and field information
   i. List of Sampling Units (SU) with the following information
      1. Soil series and related water holding capacities (WHC) and infiltration rates.
      2. Irrigation system type(s)
      3. Irrigation system specifics (nozzle size; output; etc.)
   ii. Map with soils and topography

b. Documentation of the scientific method used for scheduling water applications
   i. A Water Balance Method will be used which contains the following components:
      1. Measurement of stored soil water.

2. Measurement of the water withdrawals from the soil, plant system
3. Measurement of the applied water as irrigation or rain.

c. Method to measure stored soil water

i. Equipment

1. Decagon Devices Ech2o data loggers (with 5 ports), capacitance sensors, electronic rain gauge and a manual rain gauge.
2. 4' open face soil probe (as a backup in case of possible short-term equipment failure) for verification of soil moisture and for calibration of sensors.
3. Auger or post-hole digger or shovel for digging a hole for sensor installation.

ii. Equipment installation

1. Sensor location will be documented with GPS coordinates
2. Installation area should be located in typical soils and topography to best represent the majority of the field.
3. Auger or dig a hole to 36" depth or to the depth of hardpan or rock.
4. Label and install sensors within the soil profile using a tape measure to define depth as follows:
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1. Measure or calculate soil bulk density (BD) for each field and soil depth by collecting soil from depths of 1', 2', and 3' as near as possible to the sensors without altering their function.
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1. The Outlook, Wa. AgWeatherNet weather station will be utilized to document and project crop water use through the use of the following:
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e. Method to measure water applications

1. Flow meters on delivery pipes and/or pivots can be used to measure total water applied (gross)
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g. Other

i. Irrigation system uniformity estimation/calculation. If the system uniformity is suspect, then a calculation of uniformity should be made through the use of a rain gauge grid evaluation.

ii. Normal operation and maintenance of the plan will need to be done on an annual basis as needed.

References

- NRCS Conservation Practice Specification, Irrigation Water Management, Code 449
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- NRCS Conservation Practice Standard, Irrigation System, Tailwater Recovery, Code 447
- USDA –Soil Conservation Service, National Engineering Handbook, Sec. 15, Irrigation, Soil-Plant-Water Relationships

Appendix B

EC-5 Manual

EC-5

Soil Moisture Sensor

User's Manual

Version 2

DECAGON DEVICES

Decagon Devices, Inc.
2365 NE Hopkins Court
Pullman WA 99163 USA
(509) 332-5600

Trademarks:
“ECH2O” is a registered trademark
of Decagon, Devices, Inc All rights reserved..

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1. Introduction

EC-5 Specifications

Measurement Time: 10ms (milliseconds)

Accuracy: at least 0.03 m^3/m^3 all soils, up to 8 dS/m
With soil-specific calibration: ±.02 m^3/m^3 (±2%)

Resolution: 0.001 m^3/m^3 VWC in mineral soils, 0.25% in growing media

Power Requirements: 2.5VDC - 3.6VDC @ 10mA

Output: 10-40% of excitation voltage (250-1000mV at 2500mV excitation)

Operating Environment: -40 to +60 °C

Range of Measurement: 0 to saturation

Sensor dimensions: 8.9cm x 1.8cm x 0.7cm

Cable length: 5m standard, custom lengths or extension cables are available

Connector types: 3.5 mm plug or stripped and tinned lead wires

Data Logger Compatibility (not exclusive):
Decagon: Em5b, Em50 series loggers
Campbell Scientific: CR10X, 21X, 23X, CR1000, CR3000, etc.

Customer Support

If you ever need assistance with your EC-5, or if you just have questions or feedback, there are several ways to contact us. Customer service representatives are available to speak with you Monday thru Friday, between 7am and 5pm Pacific time.

***NOTE**: If you purchased your EC-5 through a distributor, please contact them for assistance.*

E-mail:
support@decagon.com or sales@decagon.com

Phone:
1-509-332-5600

Fax:
1-509-332-5158

If contacting us by email or fax, please include as part of your message your name, address, phone, and fax number along with a description of your problem.

Warranty Information

The EC-5 has a 30-day satisfaction guarantee and a one-year warranty.

Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2. About the EC-5

The two-prong design and higher measurement frequency allows the EC-5 to measure VWC from 0 to 100% (VWC of saturated soils is generally 40-60% depending on the soil type) and allows accurate measurement of all soils and soilless medias with a wide range of salinities.

Sensor Features

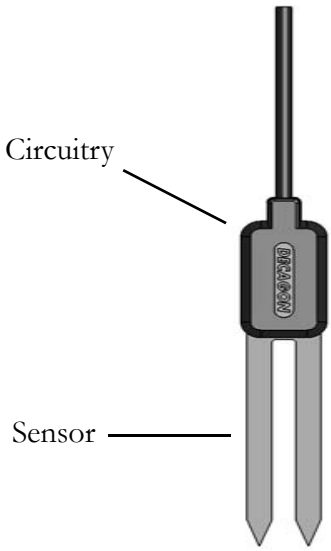


Fig. 1: EC-5 diagram

Wiring Diagrams

3.5mm Plug Wiring

The EC-5 comes with a 3.5mm "stereo plug" connector. This allows for rapid connection directly to Decagon's Em50 and Em5 loggers and the ProCheck. Below is a diagram showing the wiring configuration for this connector.

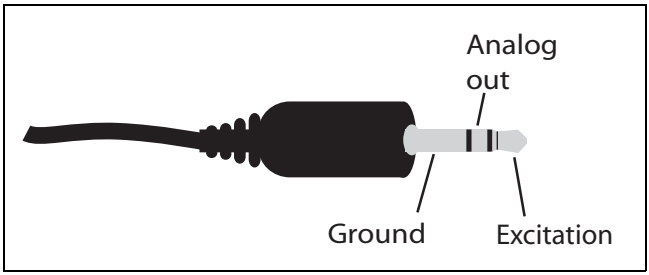


Fig. 2: 3.5mm "Stereo Plug" wiring configuration

Wiring to Non-Decagon Data Loggers

Models with stripped and tinned leads are pre-configured for connecting to non-Decagon data loggers. Simply wire the lead into the data logger as described in "Connecting to a Data Logger" in Chapter 4.

If your model uses the standard 3.5mm plug, you have two choices when attaching the sensor to non-Decagon data loggers. First, you can clip off the plug on the sensor cable, strip and tin the wires, and wire it directly into the data logger. This has the advantage of creating a direct connection with no chance of the sensor becoming un-plugged; however, it then cannot be used in the future with a Decagon Em50 or Em5 logger. The other

choice is to obtain an adapter cable from Decagon. The 3-wire sensor adapter cable has a connector for the sensor jack on one end, and three wires on the other end for connection to a data logger (this type of wire is often referred to as a "pigtail" adapter). Both the sensor wire and adapter cable wire have the same wire output (shown in Fig. 3); the white wire is excitation, red is output, and the bare wire is ground.

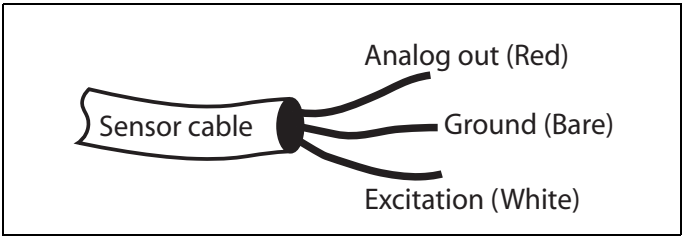


Fig. 3: 3-wire cable wiring configuration

Extended cable lengths

Decagon recommends that you purchase customized cable lengths if your project requires longer cable leads. Custom cable lengths may be requested with a 3.5mm connector or stripped & tinned end.

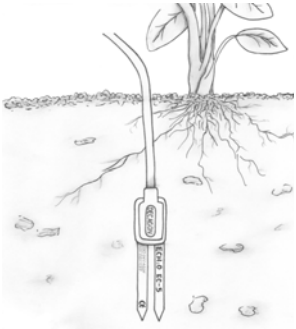
3. Installing the Sensors

When selecting a site for installation, it is important to remember that the soil adjacent to the sensor surface has the strongest influence on the sensor reading and that the sensor measures the *volumetric* water content. Therefore any air gaps or excessive soil compaction around the sensor can profoundly influence the readings. Also, do not install the sensors adjacent to large metal objects such as metal poles or stakes. This can attenuate the sensor's electromagnetic field and adversely affect output readings. Because the EC-5 has gaps between its prongs, it is also important to consider the size of the media you are inserting the sensor into. It is possible to get sticks, bark, roots or other material stuck between the sensor prongs, which will adversely affect readings. Finally, be careful when inserting the sensors into dense soil, as the prongs will break if excessive sideways force is used when pushing them in.

Procedure

When installing the EC-5, it is best to maximize contact between the sensor and the soil.

1. The EC-5 sensor was designed for easy installation into the soil. After digging a hole to the desired depth, push the prongs on the sensor into undisturbed soil at the bottom of the hole or into the sidewall of the hole. Make sure that the prongs and black overmolding are buried completely as shown below.



The sensor may be difficult to insert into extremely compact or dry soil. If you have difficulty inserting the sensor, try loosening the soil somewhat or wetting the soil. ***Never pound it in!***

2. Carefully backfill the hole to match the bulk density of the surrounding soil. Be careful not to bend the black overmolding connecting the sensor to the cable.

To watch a video on proper installation of the sensor go to www.decagon.com/install.

Orientation

The sensor can be oriented in any direction. However, orienting the flat side perpendicular to the surface of the soil will minimize effects on downward water movement.

Removing the Sensor

When removing the sensor from the soil, ***do not pull it out of the soil by the cable!*** Doing so may break internal connections and make the sensor unusable.

4. Collecting Data

Data Logger Requirements

The EC-5 sensor is designed to work most efficiently with Decagon's 5-channel Em5b, Em50, or ProCheck handheld readout. All Decagon readout devices use a 3.0V excitation.

The sensors however, may be adapted for use with other data loggers, such as those from Campbell Scientific, Inc., for example. The EC-5 requires an excitation voltage in the range of 2 to 3.6 volts. The sensors produce an output voltage that depends on the dielectric constant of the medium surrounding the sensor, and ranges between 10 and 50% of the excitation voltage. Any data logger which can produce a 2.5 to 3.6V excitation with approximately 10 millisecond duration and read a volt-level signal with 12-bit or better resolution should be compatible with the EC-5 sensor. The current requirement for the EC-5 is 10mA at 2.5V.

NOTE: *EC-5 sensors are intended only for use with data loggers and readout devices which can provide short excitation pulses, leaving the sensors turned off most of the time. Continuous excitation not only wastes battery power, but may, under certain circumstances, cause the sensor to exceed government specified limits on electromagnetic emissions. Do not continuously power the EC-5 sensor.*

Connecting to a Data Logger

Connect the wires to the data logger as shown, with the supply wire (white) connected to the excitation, the analog out wire (red) to an analog input, and the bare ground wire to ground:

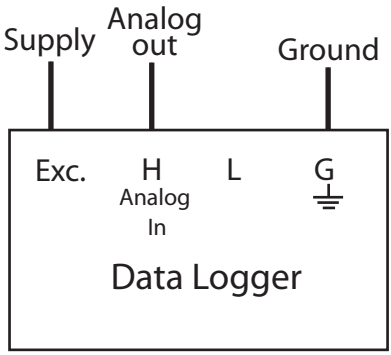


Fig. 5: Data logger configuration

Sample Program

The following program is an example that can be used with Campbell Scientific's CR10X data logger and our EC-5 sensor at a 2500mV excitation:

```
;{CR10X}
;   Example ECH2O Data Logger Program for CR10X

;   Wiring:

;   White: Excitation Channel 1
;   Red: Input Single Ended Channel 1
;   Black: Ground

*Table 1 Program
```

```
  01: 1        Execution Interval (seconds)

;   Factory calibration equations for ECH2O
;   probes convert mV output of ECH2O to
;   volumetric water content (VWC, m3/m3)

;   EC-5:   VWC = 0.00119 * mV - 0.400

1:  Excite-Delay (SE) (P4)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 1        SE Channel
 4: 1        Excite all reps w/Exchan 1
 5: 1        Delay (0.01 sec units)
 6: 2500     mV Excitation
 7: 1        Loc [ Probe_VWC ]
 8: .00119   Multiplier
 9: -.4      Offset

*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

SCWin (Short Cut) Directions

The following are instructions for using Campbell Scientific's SCWin (Short Cut) program to read the EC-5 soil moisture sensor.

1. Download EchoCSI.zip from http://www.decagon.com/appnotes/EchoCSIappnote.pdf.
2. Unzip the folder EchoCSI.zip.
3. Locate the file containing SCWin.exe. It should be in C:\Program Files\Campbellsci\SCWin. Place the

following files from the unzipped EchoCSI.zip folder into the folder with SCWin.exe:

AM1632Z.MUX
AM416Z.MUX
EC10.SCS
EC101632.SCS
EC10416.SCS
EC20.SCS
EC201632.SCS
EC20416.SCS
EC5.SCS
EC5632.SCS
EC5416.SCS
SCWIN-DECAGON.CNT
SCWIN-DECAGON.HLP

Note: *If you are not able to find this directory path, search for the folder that contains SCWIN.exe and place the files into that folder.*

4. Open up SCWin.exe (Short Cut). If you are using a V.3 copy of LoggerNet, there is a tab for SCWin (Short Cut) on the tool bar.

5. Select "New" to start a new program to read the EC-5.
   a. Select the data logger you will be using to read the sensors.
   b. Select the measurement interval (a shorter measurement interval, i.e. 1 sec., is sometimes desirable when testing the sensor).

6. Click on Sensors (this should open a new page with a file tree on it).

7. Under the "Sensors" file tree, double-click on "Meteorological" and then select "Soil Moisture."
8. Choose "EC-5" Sensor.

Calibration

Decagon's ECH_2O Utility, and DataTrac3 automatically apply factory calibrations to the sensors' output data. However, this general calibration may not be applicable for all soil types. For added accuracy we encourage our customers to perform soil-specific calibrations.

The calibration equation that you will use depends on where you will be using it. If you will be using it with sensors connected to a non-Decagon data logger you will need to use the 2500 mV calibration. If you use any Decagon software (DataTrac3, ECH_2O Utility, etc.) or the user calibration menu in the ProCheck, you will need to use the RAW calibration. The difference between the two is the slope constant. To increase the resolution of the sensor output, Decagon uses all available increments of the 12-bit number (value of 4096) where the measurement is stored. Thus, the output of the sensors read by the ProCheck and Decagon loggers must be multiplied by 0.61 AND the 2500 mV slope to give the right value.

Sensor Calibration Values

Following is a list of the both the millivolt and RAW calibration values for the EC-5, where θ is the volumetric water content, mV is the millivolt output of the sensor, and where x is the RAW sensor output.

The EC-5 is much less sensitive to variation in texture and electrical conductivity because it runs at a much higher measurement frequency. Therefore, its general calibration equation should apply for all mineral soils up to 8 dS/m saturation extract. Its calibration equations are shown below for mineral soil, potting soil, and rock-wool growing media:

Dielectric Permittivity

Dielectric permittivity can be used to determine volumetric water content using external published equations such as the Topp equation. Dielectric permittivity is given by

$$\varepsilon = 1/(-1.10570 \times 10^{-9} * RAW^3 + 3.57500 \times 10^{-6} * RAW^2 - 3.95570 \times 10^{-3} * RAW + 1.53153)$$

where RAW is the output from the Decagon data logger using 3V excitation. If you are using a non-Decagon data logger, dielectric permittivity is given by

$$\varepsilon = 1/(-3.33260 \times 10^{-9} * mV^3 + 7.02180 \times 10^{-6} * mV^2 - 5.11647 \times 10^{-3} * mV + 1.30746)$$

Mineral Soils

According to our tests, a single calibration equation will generally suffice for all mineral soil types with electrical conductivities from 0.1 dS/m to 10 dS/m saturation extract. Volumetric water content (ø) is given by

$$ø = 8.5 * 10^{-4} * RAW - 0.48 \quad (1)$$

where *RAW* is the output from the Decagon data logger using 3V excitation. If you are using a non-Decagon data logger, VWC is given by

$$ø = 11.9 * 10^{-4} * mV - 0.401 \quad (2)$$

where mV is the output of the sensor when excited at 2500 mV. Please note that the equation will reach a maximum at ~60% volumetric water content (VWC) in pure water. To display data on a scale from 0 to 100%, VWC should be modeled with a quadratic equation (which would result in a 100% VWC in water), but a linear equation fits the mineral soil VWC range as well as the quadratic, and linear equations are easier to deal with, especially since mineral soil typically saturates at ~40 - 50% VWC.

Potting soil

The following equations can be used to convert EC-5 output to water content in potting soil. We tested several types of potting soil (Sunshine mix, Miracle Grow Potting Mix, and Custom Nursery soil) at several salinities and found that VWC is given by

$$ø = 1.3 * 10^{-3} * RAW - 0.696 \quad (3)$$

for a Decagon data logger or

$$ø = 2.11 * 10^{-3} * mV - 0.675 \quad (4)$$

for a data logger with 2500mV excitation.

Rockwool

The EC-5 was calibrated in Grodan Master rockwool with solution electrical conductivities of 0.2, 1.0, 1.5, 2.0, and 4.5 dS/m. Volumetric water content can be calculated using

$$ø = 6.28 * 10^{-7} * RAW^2 + 1.37 \times 10^{-4} * RAW - 0.183 \quad (5)$$

for a Decagon data logger or

$$ø = 2.63 * 10^{-6} * mV^2 + 5.07 \times 10^{-4} * mV - 0.0394 \quad (6)$$

for a data logger with 2500 mV excitation.

NOTE: *These calibration constants only apply to 2500mV excitations; use of these numbers with any other excitation voltage will result in erroneous readings*!

Troubleshooting

If you encounter problems with the EC-5, they most likely will manifest themselves in the form of incorrect or erroneous readings. Before contacting Decagon about the sensor, do the following:

- **Check to make sure the connections to the data logger are both *correct* and *secure*.**
- **Ensure that your data logger's batteries are not dead or weakened.**

If you encounter problems that aren't due to the data logger, please contact Decagon at **(509) 332-5600** or at **support@decagon.com**.

Declaration of Conformity

Application of Council Directive:	89/336/EE6
Standards to which conformity is declared:	EN61326 : 1998 EN51022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Court Pullman, WA 99163 USA
Type of Equipment:	Soil moisture sensor
Model Number:	EC-5
Year of First Manufacture:	2001

This is to certify that the EC-5 ECH_2O soil moisture sensor, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

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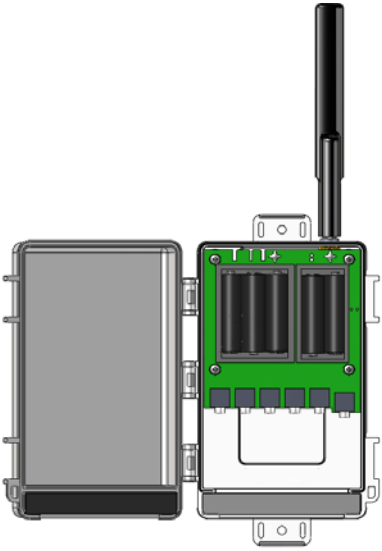
Appendix C

EM 50 Manual

Em50/Em50R/Em50G

Em50 Series Data Collection System

User's Manual



Version 12

DECAGON DEVICES

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Pullman, WA 99163 USA

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1. Introduction

Thank you for choosing the Em50 data logger series. These data loggers are designed and suited for field research and commercial agriculture. This manual will explain the Em50's capabilities and functions.

NOTE*: Except where specified, all functions and specifications relating to the Em50 also relate to the Em50R and the Em50G.*

Customer Support

If you ever need assistance with your Em50, or if you just have questions or feedback, there are several ways to contact us Customer Service Representatives are available to speak with you Monday thru Friday, between 7am and 5pm Pacific time.

NOTE*: If you purchased your Em50 through a distributor, please contact them for assistance.*

E-mail:
support@decagon.com or **sales@decagon.com**

Phone:
1-509-332-5600

Fax:
1-509-332-5158

If contacting us by email or fax, please include as part of your message your instrument's serial number, your name, address, phone, and fax number.

You can also send feedback to Decagon using ECH_2O Utility's "Send Feedback to Decagon" feature. See Appendix B for more information.

Specifications

Input Ports: 5, 12-bit analog or 32-bit digital

Port type: 3.5mm "stereo jack" connector

Data Storage: 1MB (36,800 scans for all 5 ports)

Memory type: Non-Volatile Flash

Battery capacity:5 AA Alkaline or Lithium batteries

Enclosure: Weatherproof, impact and UV-resistant polymer

Enclosure rating: IP55, NEMA3R

Operating environment: 60° to -40°C, up to 100% RH

Communication: Dedicated serial port 3.5mm stereo jack for use with the Decagon USB Cable Adapter (UCA).

Radio (Em50R models):

902 - 928 MHz ISM *North America*
915 - 928 MHz ISM *Australia, New Zealand, Israel*
2.4 GHz ISM *Worldwide*

Cellular (Em50G): *GSM/GPRS Cellular technology. Cellular service and data hosting service provided by Decagon Devices.*

Software Downloads and Updates

Go to www.Decagon.com/support/downloads if you need to download firmware updates, software updates and/or drivers.

Warranty

All Decagon products have a 30-day satisfaction guarantee and the Em50 has a one-year warranty.

Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2. Em50/Em50R/Em50G

Em50 Logger Series Overview

Introduction
The ECH_2O System is made of data loggers, sensors, telemetry, and software that help you measure soil moisture and other environmental parameters accurately and cost effectively. Decagon's innovative sensors are the heart of the system. Decagon also designed the system to be very easy to use (no programming needed).

About the Em50 Logger Series. The Em50 is a 5-port, self-contained data logger especially suited for field research and commercial agriculture. The Em50 logger series includes three models: the Em50, the Em50R and the Em50G. These devices are housed in a weather-resistant enclosure, making them suitable for long-term outdoor operation.

Em50
The Em50 is the basic logger. The communication with this model is through a stereo to USB or stereo to Serial cable to a PC or mobile handheld device.

Em50R
The Em50R includes a spread-spectrum radio telemetry module. The radio module is available in long-range 900 MHz and 2.4 GHz frequencies. Use the telemetry in energy efficient transmit mode or two-way mode. (See Chapter 6 for more information on telemetry.)

Em50G

The Em50G includes a GSM/GPRS (Global System for Mobile communications/General Packet Radio Service) cellular module to allow environmental measurement data available over the internet. Decagon partners with a provider of global cellular data service to make data transmission and maintenance easy and inexpensive. Measurements from the Em50G are sent wirelessly to Decagon's internet server and are available for download using DataTrac 3 software or the Em50G WebViewer.

Em50 Compatible Sensors

You can use the Em50 to log data for almost all of the sensors that Decagon sells (excluding the UMS and thermal sensors). Please see our website (www.decagon.com) or our catalog for an up-to-date list of supported sensors.

Software

The Em50 series gives you two software options for working with your hardware and collected data. Choose one or both packages to fit your needs. Download the latest versions of these programs at **www.decagon.com/support/downloads.**

ECH_2O Utility

ECH_2O Utility is free software that is included with your purchase. It provides a simple way to connect to and configure your loggers. The ECH_2O Utility makes downloading and processing your measured data fast and easy.

- Connect to Em50 loggers directly or with radio telemetry.
- Set all logger configuration parameters with visual controls.
- Make real-time sensor measurements (scan sensors).

- Create Excel or text files with raw or processed data.
- Create configuration and data files for use with DataTrac.

DataTrac 3

DataTrac 3 is the premier Em50 series system software designed to help you organize and visualize your measurement data. DataTrac 3 transforms endless columns and rows of raw data into meaningful, easily-interpreted graphs. DataTrac 3 comes with the Em50 system as a 30-day trial version. If you would like to continue to use DataTrac 3, contact Decagon to purchase a DataTrac 3 registration code. With DataTrac 3 you can:

- Explore trends and relationships in real time.
- You can adjust date ranges, add or subtract data from specific sensors, and change target bands to illustrate and explore your findings. Powerful charting engine shows data graphically.
- Use DataTrac 3's Growing Tools to combine data streams and track meaningful indicators. For example, plot vapor pressure deficit instead of just temperature and humidity. Or track growing degree days, plant available water, pore water EC, etc.
- Use the "virtual sensor" tool to add information you wish you had. For example, you can measure precipitation on just one logger and make that data stream a "virtual sensor" on every logger at that site.
- Automatically collect data from your Em50G and Em50R loggers. All data—including manually collected data--will be automatically organized and added to your files chronologically.

- Watch your data in real time. DataTrac 3 updates automatically while it's running and every time it starts up.
- Add notes and ideas to the data stream. Comments and reminders can help you make sense of a growing season's worth of data later.
- Educate and inform your team efficiently. DataTrac 3's graphics reduce the time and expertise needed to understand soil moisture data.
- With this much data, you can spend enormous amounts of time scrolling through looking for answers. DataTrac 3 lets you explore your data graphically and discover quicker answers and unexpected insights.

<u>ECH_2O Utility Mobile</u>

ECH_2O Utility Mobile is designed to bring the usefulness of ECH_2O Utility to Windows powered mobile devices or handheld computers (PDA). Use this software and your PDA in the field instead of your expensive laptop. This software will configure your logger, download data, and make real-time sensor measurements. Like the desktop version, ECH_2O Utility Mobile allows you to:

- Connect directly or with radio telemetry to Em50 loggers.
- Set all logger configuration parameters with visual controls.
- Make real-time sensor measurements (scan sensors).
- Creates configuration and data files for use with DataTrac 3.
- Creates data files for use with ECH_2O Utility.

ECH_2O Utility Mobile works with most Windows PDAs, including the HP iPAQ. Decagon Recommends using the Juniper Systems Archer field PC (available from Decagon). This

ultra-rugged mobile device is designed to work in field conditions where typical PDA hardware will fail. Please see the ECH_2O Utility Mobile manual for more information on system requirements to use your PDA with the ECH_2O System.

Em50G WebViewer

The Em50G WebViewer is a free web-based application that allows you to remotely download spreadsheets and view weekly graphs of your data without a DataTrac 3 license. For more information on the Em50G WebViewer, see Chapter 4.

Em50 Series Data Logging Scheme

The Em50 will not make sensor measurements until you set a measurement interval. You also need to configure the Em50 ports with the type of sensor plugged into each port. You can set these values using the software described in the previous section.

Em50 Measurement Interval

The measurement interval controls how often data is recorded in the Em50's internal data storage. The interval you choose applies to all 5 ports on the Em50, therefore, it is not possible to have one port measuring sensors more or less frequently than another port.

The measurement interval works relative to the Em50's internal real-time, 24-hour clock. For example, when choosing a measurement interval of 120 minutes, the Em50 will store data every two hours, on the hour. The resulting data will show sensor measurements hourly at 12:00 a.m., 2:00 a.m.,..., 10:00 p.m. Choosing a measurement interval greater than 720 results in one set of data stored per day. For most applications, a measurement interval of 60 or 120 minutes is appropriate.

NOTE: *Setting the Em50 measurement interval to zero turns off sensor measurement and data storage.*

For most sensor types, the Em50 makes a measurement from each of the 5 sensor ports every 60 seconds, regardless of the measurement interval value. When the Em50's internal clock reaches the user-programmed measurement interval, the Em50 stores the average of all the 60-second sensor readings taken since the last storage interval. Therefore, if you set the measurement interval to 60, the Em50 will actually store an average of the past 60 sensor readings. If you choose an interval of 1440, the Em50 will store one value that represents the average sensor value for the entire 24-hour period.

NOTE: *The Em50G supports 5 minutes as the minimum value for the measurement interval setting.*

Data Storage Format

The Em50 stores "raw" data for each sensor. The stored values are not in millivolt units. Please review your individual sensors operators manual or visit our website (www.decagon.com) for up to date equations to convert raw data to meaningful sensor values.

How the Em50 Stores Data

The Em50 stores data for all five sensor ports for each measurement interval. If no sensor is connected to one or more of the logger's ports, the Em50 will store a "0" for that port. The Em50's data memory is non-volatile flash. Removing the batteries or performing a system reset will not erase your data. However, it will reset the clock in the data logger. To reset the clock to the correct time, simply connect your Em50 to a computer or handheld device running ECH_2O software.

Data Storage Size

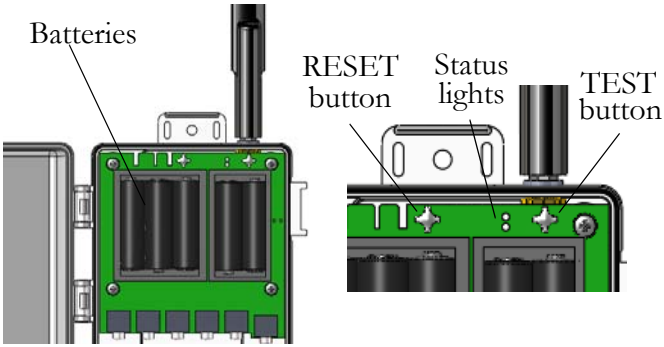
The Em50 stores more than 36,800 data scans. When the logger has filled its data memory, it begins overwriting the oldest data in the memory.

Measurement Span

Depending on the set measurement interval, the Em50 can read for several weeks to several years before its memory has filled. When you set up your Em50 using ECH_2O Utility, the software will display how many days of data the Em50 will hold based on the measurement interval that you have chosen. You can determine how many days of data your Em50 will hold by dividing the size of the data memory (36,864 scans) by the measurement interval. For example, an Em50 set on an hourly measurement interval will store 1,500 days, or about 4 years, worth of data. An Em50 set to five minutes will store data for 125 days, or about four months.

3. Setup and Installation

Installing the Batteries



The Em50s are shipped with a new set of AA alkaline batteries. Open the case and install the batteries in the proper orientation as indicated in the battery locations. After installing the batteries, press the silver Reset button located directly above the batteries.

NOTE: *Installing or changing the batteries in your Em50 resets the internal real-time clock. You must connect to your Em50 using any ECH$_2$O System software to reset the logger's clock. If you don't set the logger's clock, the time and date associated with each measurement will be incorrect.*

The Em50 is powered by 5 AA-size Alkaline batteries. With the radio or cellular modules disabled, a set of Alkaline or Lithium batteries can last for several years. The battery life for Em50Gs and Em50Rs varies depending on how the transmission is

setup. (See Chapter 6.) Battery power in the Em50R and Em50G can last from six months to over a year.

You can check the battery level status when the Em50 is connected using any ECH_2O software. When the battery life indicator shows that your Em50's batteries are less than 5%, you should replace them.

Reset Button

All Em50 logger types have a "RESET" button. If your logger doesn't respond to connection attempts or doesn't appear to be working, press the reset button. This will reboot the logger and the "STATUS" light will turn on momentarily. The internal data storage of the logger is non-volatile so you will not loose data or settings if you press the reset button.

Em50R STATUS Light

The green "STATUS" light indicates the current status of your Em50R logger.

- A short, single blink every 5 seconds indicates the Em50R is configured to log sensor data. The light doesn't blink if the logger's measurement interval is set to 0 or "Off".
- A slow on/off blink indicates the Em50R is connected to an active serial port.
- A rapid continuous blink indicates the logger's date and time are not set correctly. This can happen when the batteries have been disconnected. You must connect to your Em50R using any ECH_2O System software to reset the logger's internal clock. The logger will stop error blinking when the date is reset or after 2 minutes have elapsed (to preserve battery power).

Em50/Em50G Status Lights

The "OK" (green) and "ERROR" (red) lights indicate the current status of your Em50/Em50G logger.

- The lights indicate the status of the logger's self test function (see below).
- A short, single blink of the "OK" (green) light every 5 seconds indicates the Em50/Em50G is configured to log sensor data. The light doesn't blink if the logger's measurement interval is set to 0 or "Off".
- The "OK" (green) light blinks slowly on/off blink indicates the logger is connected to an active serial port or the cellular module is powered on.
- The "OK" (green) light pulses when the Em50G is actively sending data over the cellular network.
- The "ERROR" (red) light blinks continuously to indicate the logger's date and time are not set correctly. This can happen when the batteries have been disconnected. You must connect to your Em50/Em50G using any ECH_2O System software to reset the logger's internal clock. The logger will stop error blinking when the date is reset or after 2 minutes have elapsed (to preserve battery power). Pressing the "TEST" button may also reset the loggers clock by using the time of the cellular network if the connected network supports time information.

Em50/Em50G TEST Button

The Em50/Em50G logger has a TEST button to perform basic functionality testing. When you press the TEST button, the logger performs several checks on internal systems and attempts a communication session over the cellular network, if

an Em50G. The logger uses the status lights during the test as follows:

- Both the "OK" (green) and "ERROR" (red) lights blink slowly while the Em50G is performing the tests. Please be patient. It can take as much as 60 seconds or more to finish the cellular communication tests in the Em50G.
- The "OK" (green) light pulses when the Em50G is actively sending data over the cellular network.
- A solid "OK" (green) light indicates the internal tests passed and there was successful communication over the cellular network to the Decagon Data Service. The Em50G leaves the light on for approximately 20 seconds.
- A solid "ERROR" (red) light indicates an error in the logger or in communicating to the Decagon Data Service. Please use the Communication Test feature in ECH_2O Utility to find the specific error.

Installing Software

The ECH_2O Utility and DataTrac 3 software (installation cd is attached to the cover of this manual) allows you to collect and manage data from your device.

NOTE: *This manual documents ECH_2O Utility. Most tasks that can be performed using the ECH_2O Utility can also be accomplished using DataTrac 3 or ECH_2O Utility Mobile. For more information about using DataTrac 3 or ECH_2O Utility Mobile, please refer to their respective manuals.*

To install ECH_2O Utility, DataTrac 3, or Em50G software, place the CD in your CD drive, and wait for it to auto-launch. If it doesn't launch, go to My Computer, select your CD drive,

and click on the "setup.exe" file. A driver for the accompanying USB cable can also be installed at this time.

Occasionally, new versions of ECH_2O System software will become available on Decagon's website. They can be accessed at **www.decagon.com/support/downloads.**

You can find your current software version in the "About" option of the Help menu in the ECH_2O Utility and DataTrac 3. If you are connected to the internet, select "Check for Updates" in the Help menu to see if there is a newer version available.

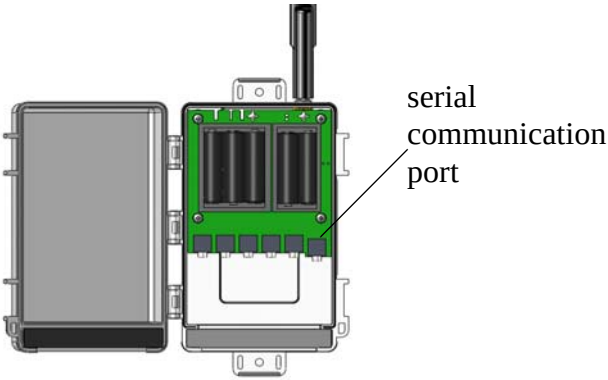
Decagon USB Cable Adapter (UCA) Driver Installation
You must install a driver for the USB Cable Adapter (UCA) before you can use it to communicate with your logger. You can find the driver installer on your ECH_2O System Software CD or from Decagon's website at www.decagon.com/support/downloads.

Configuring in ECH_2O Utility

Before field installation, the Em50 needs to have certain parameters set, such as name, date and time, measurement interval, and communication mode. Also, the radio-enabled Em50R and the cellular Em50G will not respond to wireless contact until properly configured to do so. To configure the logger, do the following:

1. Open the ECH_2O Utility program.

2. Plug the 3.5 mm connector of the UBS cable (included with your Em50) into the logger's COM port, and plug the USB into the serial port of your computer.



Port diagram

3. At the top of the screen, select the appropriate COM port from the "Connect Via" drop-down menu, then click on the "Connect" icon. If you are using the USB Cable Adapter, look for the "Connect Via" option that includes "Decagon UCA" in the COM port name.

NOTE: *If you cannot connect to your Em50, you may need to install the driver for the USB cable. To download a driver go to www.decagon.com/support/downloads.*

4. Once you have successfully connected, the menus on the main screen will become active.

5. At the device setup screen that appears, click on the various fields to enter a name for your logger and choose sensor types for each port.

   When using the Em50R, select the radio settings you plan to use (See Chapter 6). Click on "Apply" to save the changes. When using the EM50G, select your communication configurations (see Chapter 4: Software and Configuration).

6. Press the "Disconnect" icon when finished.

Field Installation

NOTE: *To watch a five minute video on installation, visit www.decagon.com/videos.*

The Em50 will serve as a collection station for up to 5 sensors. The Em50 is compatible only with sensors made by Decagon such as the ECH_2O water content probes, rain gauge, temperature sensors, etc. To install the Em50 and sensors, do the following:

1. If you are using the Em50R or Em50G, perform a telemetry test to check the wireless signal. If your signal is low or does not exist, move to an alternative location. (Sometimes only a few feet away will be sufficient.)
2. Install your sensors as directed in the respective sensor's manual.
3. Plug the sensor's jack firmly into the Em50 input port.
4. On the top and bottom of the Em50, there are two loop-holes. Use these to fasten the Em50 to a mounting post using the included zip-ties or a similar fastener. Make sure it is installed in an upright position, with the 5 input ports underneath. In this position, rain and spray are shed by the enclosure and drip off without affecting the contents of the Em50 enclosure.
5. Configure the Em50 using ECH_2O Utility, ECH_2O Utility Mobile, or DataTrac 3.

Cautions

When you install an Em50 series logger, remember:

- Do not immerse the Em50 in liquids.

- Make sure to install the Em50 upright to reduce the possibility of water entering the Em50 enclosure.
- Do not install Em50R or Em50G wireless loggers near large metallic objects, as these can attenuate the radio signal.

If the Em50R or Em50G is mounted to a metallic post, be sure to use an antenna extension cable to mount the antenna to the top of the post. This will maximize the transmit range of the Em50 wireless transmission.

4. Software & Configuration

The Em50 series data loggers were designed to have simple configuration and no data logger programming. The software packages below were designed to fit a variety of users.

- **ECH_2O Utility**--Use ECH_2O Utility for basic data logger configuration and direct connect data download in Excel format. For users with a windows laptop, netbook, or desktop computers.

  **ECH_2O Utility cannot download Em50G data from Decagon Data Service.*

- **DataTrac 3**--Use DataTrac 3 for configuring and organizing multiple Em50 series loggers. DataTrac 3's database system automatically updates newly downloaded data and creates graphs of complete data sets from each logger. DataTrac 3 is the premier software for downloading and collecting data from Em50R or Em50G systems. This software is best if you are interested in viewing your data on a daily or weekly basis because of the software's ability to automatically append new data collected by each logger.

- **ECH_2O Utility Mobile**--Use ECH_2O Utility Mobile to configure and download data on Em50 data loggers when using a handheld device such as an Archer or iPAQ running Windows Mobile.

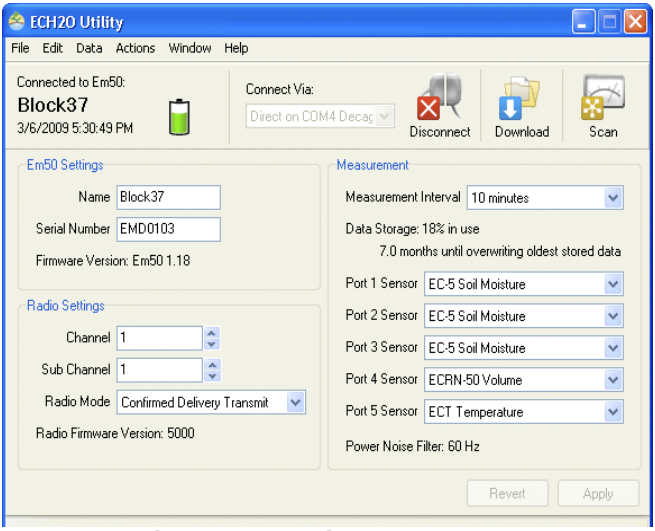
- **Em50G WebViewer**--Use the Em50G WebViewer application when you do not have a DataTrac 3 license to remotely download Microsoft Excel spreadsheets of your

data, and view graphs of your data for the past week through the Decagon Data Service.

DataTrac 3 and ECH_2O Utility Mobile have their own designated manuals. Instructions for ECH_2O Utility and the Em50G WebViewer are included here.

ECH_2O Utility

ECH_2O Utility provides a user-friendly interface for configuring and downloading data from the Em50 logger. After installing the program (see Chapter 3: Setup and Installation for instructions), launch the program. You will see the main screen:



The ECH_2O Utility Main Screen

Here you can set all logger configuration parameters with visual controls. At the top of the program window is a toolbar for interacting with the Em50. To the left is a battery indicator. To the right is the "Connect Via" menu, where you can select a

COM port; the Connect button (which displays "Disconnect" when you are connected to an Em50); the Download button, which downloads data saved on the Em50 onto your computer; and the Scan button, which scans all of the sensors connected to each port on the Em50, and returns a real-time reading. These functions will be described in detail further in this chapter. Below are the most common tasks that can be performed with the ECH_2O Utility, explained in detail.

Common Tasks in ECH_2O Utility

Configuring the Em50/Em50R/Em50G

The Em50 doesn't require any programming. It does have several parameters that control identity and function. To change a parameter, connect to your device, change the desired parameter, then click "Apply" to send the parameter changes to your device. Here is a brief description of each:

Name. Each Em50 device should have a unique name. The default name is the unit's serial number. You can change this to any legal name you want. A legal device name uses upper and lower case letters, numbers, underscores, and hyphens. Spaces and most punctuation are not legal name characters. ECH_2O Utility prevents you from choosing a name containing illegal characters.

Serial Number. When set in the factory, this is a read-only value.

Measurement Interval. The Em50 and Em50R loggers allow you to select a measurement interval between 1 and 1440 minutes while the Em50G allows you to set a measurement interval between 5 and 1440 minutes. A measurement interval of zero (0) or "off" stops the logger from making measurements.

Port Sensors. The Em50 requires you to identify the sensor type for each of the five sensor ports.

Cellular Settings. To turn the cellular network of the Em50G on or off, click the "Configure" button in the "Communication Option" section. The cellular network is active when "Upload data to ECH_2OData.com" box is checked and is off when the box is not checked. The Em50G is uploading data to the Decagon Data Service ("on") by default. See Chapter 5. Em50G Cellular Communications for more information on the Em50G.

Choose up to six upload times. Default upload times are: 6-7 AM, 10-11 AM, 1-2 PM, 4-5PM. To conserve battery power, choose fewer upload times.

Click "OK" after making configuration changes. Click "Apply" to save communication settings in your Em50G. Your current settings will show up in the communications option field.

ECH_2O Utility helps you evaluate the quality of the cellular connection on your Em50G with the Communication Test feature. Please see Chapter 5. Em50G Cellular Communication for a step-by-step guide to running the Communication Test.

Radio Settings. Only devices that have a radio module will support these options (Em50R, DataStation). See Chapter 6: Em50R Radio Telemetry for more information on using the radio settings.

<u>Downloading Data when Directly Connected</u>
Once the Em50 is properly configured and installed, it will begin making and storing sensor measurements. Stored data can be downloaded from the logger starting at two places in the

logger's memory. The "Download New" option downloads the data stored since the last successful download. The "Download All" option downloads all the data currently stored in the Em50. The "Download" button on the toolbar corresponds to the "Download New" option. Any model of Em50 data logger supports downloading data when directly connected to the logger with ECH_2O System software.

To download data, do the following:

1. Use the USB cable to connect the Em50 to your computer.
2. Choose "Direct on" the appropriate COM port from the "Connect Via" drop-down list and press the "Connect" button. If you encounter connection errors, please see Chapter 11: Troubleshooting or the ECH_2O Utility Help File.
3. Once connected to an Em50, either click the "Download" button on the toolbar, or go to the Data Menu and select a download option as described above.
4. When saving data, the File Save dialog suggests a name based on the connected logger's name and the time and date. However, you can enter any name by typing it into the "File name" field.
5. Choose the file format you prefer then click "Save". ECH_2O Utility will download the data and create the file.

ECH_2O Utility can save your data in several different file formats:

- **Excel Workbook File (.xls)**: Converts the raw down-loaded measurement data into engineering values appropriate for each sensor type. The converted data are saved to sheet 1 of the workbook. Raw data are saved to sheet 2. You can use the raw measurement data to apply custom calibration to your sensor data.

- **DataTrac Data File (.dxd)**: Saves the file in a format that DataTrac can import. Each dxd file contains information about the ECH_2O logger's settings, identity, and status along with the raw data for each sensor.
- **Processed Data Text File (.txt)**: Converts the raw downloaded data into engineering values appropriate for each sensor type. Data are saved as a tab delimited text file.
- **Raw Data (.csv)**: Saves the raw data in the form downloaded from the logger.

NOTE: *The DataTrac file format (.dxd) is a useful way to store data for later manipulation. Each .dxd file contains information about the ECH_2O logger's settings, identity, and status along with the raw data for each sensor. ECH_2O Utility will process a .dxd file into an Excel file or a processed text file. This allows you to re-process your raw data with different settings or file formats as needed.*

Other Data Download Options

An Em50R supports downloading data wirelessly. ECH_2O Utility can establish a two-way radio connection between your computer and a remote Em50R through the Rm1 Radio Modem. Once this connection is established, downloading data from the Em50R is handled just like a download when directly connected to the logger. See Chapter 6. Em50R Radio Telemetry for more information on setting up two-way wireless communications.

The Em50R also supports wireless sensor networks. In this mode, the Em50R transmits measurement data to a DataStation. You can then download the measurement data from all the Em50Rs in your network from one location. See Chapter 6. Em50R Radio Telemetry for more information on setting up logger networks.

The Em50G logger is designed to upload your measurement data to Decagon Data Service using the cellular network. This makes it easy for you to use the internet to download your measurement data from anywhere in the world. Please see Chapter 5: Em50G Cellular Communications for more information.

NOTE: *ECH_2O Utility uses the default conversion equation for each sensor when converting raw data to processed data. For more information about the default conversion equations, please see your logger or sensor manual.*

Erasing Data

If you need to erase the data on your Em50, go to Data > Erase Stored Data. You should erase your data if you change the Em50's configuration settings, such as what type of sensor is in each port. After selecting the Erase option, you will be asked if you want to continue. Click Cancel to return to the program, or Erase Data to continue.

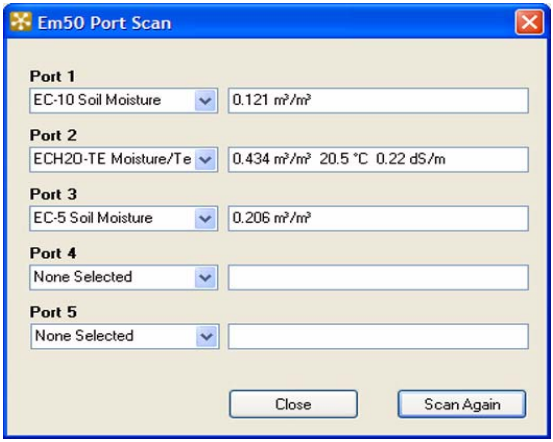
WARNING! Once this feature is activated, ALL stored data will be erased and cannot be recovered!

Instantaneous Measurements (Scan)

The ECH_2O Utility gives you the ability to take real-time sensor measurements with your Em50 logger. This is most useful as a troubleshooting feature to test if a sensor is reading properly. You can also see how sensors react to environmental changes. To take this type of reading:

1. Click the "Scan" button in the toolbar, or go to Actions > Scan Logger Ports. The Em50 will take a reading on each

of the ports, then display a screen similar to the one below.



2. All 5 ports are displayed, along with the measurement for each port in the units appropriate for the sensor. You can change measurement units in the Preferences Menu (see "Measurement Units" in Chapter 5). Click the sensor's name to see the reading as raw data.

The five ports are displayed, along with the measurement for each port in the current selected unit. If nothing is plugged in to a port, the reading for that port will be zero.

NOTE: *Data measured with the scan function will not be stored in the Em50.*

ECH_2O Utility Menus

The ECH_2O Utility features six menus that allow you to access the program's features. This chapter discusses the features of each menu.

The File Menu

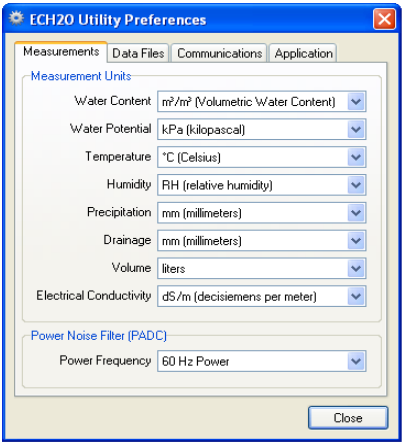
Save Settings File. Selecting the "Save Settings File" option from the File menu will create a data file that contains all of the settings and information associated with the connected Em50. This feature is useful for transferring logger configurations between ECH_2O Utility and ECH_2O DataTrac. By default, the name of the settings file is the name of the selected Em50. After naming the file and selecting where it will be saved, click Save to create the file.

Convert Data File. ECH_2O Utility will "process" or convert raw ECH_2O sensor data to processed data. This feature works by reading a file containing raw data and outputting the processed data into a different file. You can convert DataTrac data files (*.dxd) and EchoLink download files (*.csv or *.txt). Only files saved with ECH_2O Utility and ECH_2O Utility Mobile can be converted to processed files. You can choose to save your processed files as an Excel file or text file.

Edit Menu

The Preferences Menu. The main feature of the Edit Menu is the Preferences menu. The Preferences menu features four tabs for navigation: Measurements, Data Files, Communications, and Application. Below are a list of the most common tasks that can be performed in each tab.

1. Measurements Tab



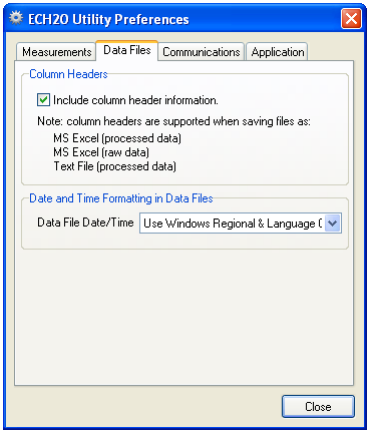
Measurement Units. These are the unit values that will be displayed when downloaded data are saved as Excel, processed, or raw data files. ECH_2O Utility supports displaying some measurement data in multiple units. For example, it allows you to choose degree Celsius or degree Fahrenheit for temperature sensors. To set your preferences for measurement units, choose the "Measurements" tab in the ECH_2O Utility Preferences window.

Locate the type of measurement and select a unit from the drop-down menu next to it. Click "Close" to apply the changes.

Power Noise Filter. The AC electrical power in your office or home can add a subtle amount of noise to the data logger sensor measurements. The logger's Power Noise Filter setting is designed to eliminate this electrical noise that comes from the AC power distribution system. You should set the value of the Power Noise Filter to match the frequency of the power cycle where you live. In North America and most of Asia, this is 60 Hz (the default value). In most of Europe the electrical frequency is

50 Hz. This feature only needs to be set once, as the program will automatically update the filter of each device that it connects to.

2. Data Files Tab

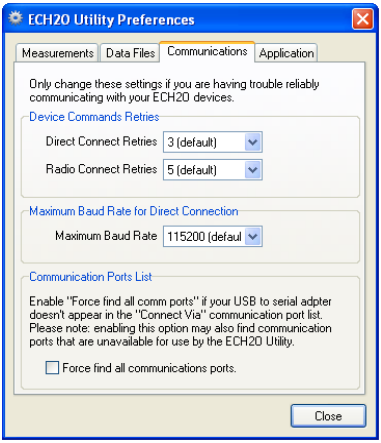


Column Headers. The column header gives each column a title corresponding to the port number, measurement type, and unit. Column headers for saved data files are turned on by default, and apply only to processed and raw MS Excel data, as well as processed text data. De-select "Include column headers" to turn off the column headers for these file types.

Setting Date/Time Format for Data Files. You can control how the date and time values are formatted in the data file. By default, the time and date are formatted using the settings in the Windows Regional & Language Options control panel. You can modify this to display the date and time in dd/mm/yyyy format with either a 12- or 24-hour clock. To change the format, select an option from the menu, then click "Close" to apply the changes.

3. Communications Tab

The Communications preference tab has items that control how the serial communication works between ECH_2O Utility and your Em50. Generally you should not adjust these settings unless you are experiencing problems communicating with your Em50.



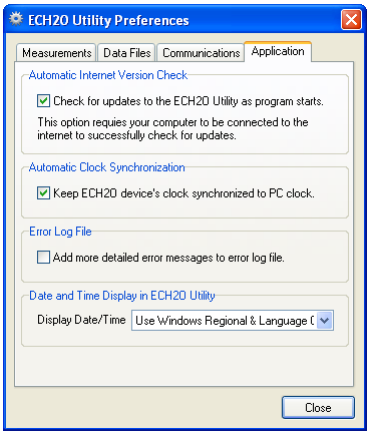
Direct Command Retries. ECH_2O Utility automatically retries commands it sends to your Em50 when there are errors. For most circumstances, the default retries work well. If you experience unreliable communication with your Em50, you can try increasing the Direct Connect Retries.

Maximum Baud Rate. Set a baud rate lower than the default 115,200 baud if you consistently experience serial connection problems.

Communications Port List. ECH_2O Utility is compatible with most USB-to-Serial adapters. Some models of USB-to-Serial adapters are not found by the serial port enumeration feature of

ECH_2O Utility. If your model of USB-to-serial adapter is not recognized, enable "Force find all Communication Ports" in the Preferences Menu by going to the Communication tab, and enabling the check box at the bottom of the screen. Enabling this option may find other serial ports that are not available for use by the ECH_2O Utility (for example, modems installed in your computer).

4. Application Tab



Automatic Internet Version Check. ECH_2O Utility will automatically check for a newer version using Decagons internet version-check engine. When this option is selected, it will notify you when a newer version is available if you are running ECH_2O Utility, and if your computer is connected to the internet. You can turn off the automatic check by un-checking this option. You can manually check for updates any time using the "Check for ECH_2O Utility Updates" option in the Help menu.

Automatic Clock Synchronization. By default, the ECH_2O Utility automatically synchronizes your logger's date and time to

the time set on your computer. You can disable this feature by un-checking this option. You can also update the date and time in your logger any time it is connected by selecting Actions > Set Date/Time.

Error Log File. The ECH_2O Utility keeps a log file of errors and events. Adding more messages to this file is useful for troubleshooting. Check this option to add more error and event messages to the error log.

Date and Time Display in the ECH_2O Utility. You can control how the date and time for your Em50 is displayed in the toolbar status area. By default, the time and date are formatted using the settings in the Windows Regional & Language Options control panel. You can modify this to display the date and time in dd/mm/yyyy format with either a 12- or 24-hour clock.

Data Menu

The Data menu has three options: **Download New Data, Download All**, and **Erase Stored Data**. For more information on these functions, please refer to their respective sections in Chapter 4.

Actions Menu

Connect/Disconnect.

Performs the same function as the connect/disconnect button in the toolbar. It initiates a data communication connection between your Em50 and your computer. You must first connect to your Em50 before downloading data.

Get Settings

This command retrieves all the port and configuration settings from your Em50. These settings are automatically collected

when you connect to your Em50. You can use this option to check to make sure your changes are stored in the Em50.

Apply Settings

Applies the parameters you changed to your Em50. This operates just like the Apply button on the main screen. This option is only available when there are parameter changes available to send to the Em50.

Scan Logger Ports

This option allows you to take readings from each port independent of the others. See the section "Instantaneous Measurements" in Chapter 4 for details and procedures.

Digital Sensor Terminal

The Digital Sensor Terminal is used for SDI-12 addressing and query of our digital SDI-12 sensors. See these sensors' respective manuals for additional information on SDI-12 capabilities.

Set the Date/Time

When you select this action, the ECH_2O Utility will set the Em50's time and date to be the same as the time and date on your computer.

Communication Test

When the Em50R or Em50G is connected using ECH_2O Utility, use "Communication Test" to see how well your logger's wireless communication is working. If the test suggests that you have a poor connection, you can move to a new location and re-try the communication tests.

Device Tools

The Device Tools submenu contains the following items:

Test Device Firmware. This option is useful in determining if you have any firmware (the internal software that runs the Em50) errors. To initiate a firmware test, select Actions > Device Tools > Test Device Firmware. This will automatically test the integrity of your Em50's firmware, and report if it reads as Bad or Good.

Initialize Radio Module. Resets the radio module to the default setting. This option applies to Em50Rs and DataStations only.

Initialize Device. Initializing your Em50 is a form of a hard reset. ECH_2O Utility resets your Em50 and re-writes all the logger settings. All your measurement data is erased. This option is useful for troubleshooting a logger that is not working as expected.

NOTE: *Initializing your Em50 will delete all stored data. Make sure any data has been downloaded out of the Em50 before initiating a reset.*

Window

The Window Menu contains the Show Terminal command. The terminal window allows you to directly enter commands for your Em50, and is mainly used for troubleshooting and diagnosis.

Help

The Help Menu allows access to the ECH_2O Utility help file, allows you to check for program and firmware updates, and displays information about your copy of the ECH_2O Utility.

ECH$_2$O Utility Help

This menu item opens the help file. It contains some of the information found in this manual.

Send Feedback to Decagon

This menu item helps you send product feedback, bug reports, or feature requests to Decagon. Your computer must be connected to the internet for this feature to work. See Appendix B for more information.

Check for Utility Updates

This function checks for the newest available version of the ECH$_2$O Utility. Make sure you are connected to the internet, then select Help > Check for ECH$_2$O Utility Updates. The program will check to see if there is a newer version available. If there is, it will direct you to the web page where you can download it. To check for a newer version of the ECH$_2$O Utility, choose this menu item. Checking for updates for the ECH$_2$O Utility uses Decagon's version-check web engine. Your computer must be connected to the internet for this feature to work.

Check for Device Firmware Updates

This menu item is only available when you are connected to an Em50 (or other ECH$_2$O device). It compares the firmware version of your Em50 with the latest version available from Decagon. You can download a firmware updater when a new version is available. Your computer must be connected to the internet for this feature to work.

About the ECH$_2$O Utility

This menu item opens the "About" window. You can see the version of your copy of ECH$_2$O Utility here.

Em50G WebViewer

The Em50G WebViewer is a web-based application that can be used to securely connect to the Decagon Data Service to download excel sheets and display weekly graphs of your data. For more specific help than what is provided here, see the Em50G WebViewer Help Files which can be found by clicking the "Help" link on the WebViewer website.

Adding a User

Upon first visiting the Em50G WebViewer, you will be required to either sign in or add an account. If you have already made an account with the Decagon Data Service through either the old Em50G downloader or DataTrac3, your account is already set up and you just have to enter your credentials to sign in. Otherwise, you must make an account. To make an account, begin by clicking on the "Create User" link below the "Sign in" button. This will bring up the Decagon Data Service Registration form. Enter the required information and click on the "Register" button at the bottom. If all goes well with your registration, you should see a page informing you that your registration was successful. Click on the "login" link, and you're ready to add new Em50G loggers to your account.

Add a Subscription

In order to view data from an Em50G, you must first "Subscribe" to it. You are not limited by the number of Em50G loggers you can subscribe to. See the Em50G WebViewer Help Files for more information on subscribing to your data logger.

5. Em50G Cellular Communication

The Em50G data logger is equipped with a GSM/GPRS cellular module that enables the logger to upload sensor measurement data to Decagon Data Service. Your measurement data is available for download directly to your Windows computer at any time, anywhere in the world where you have internet access. To extend your service plan contact Decagon at sales@decagon.com or 1-509-332-5600..

Decagon Data Service

The Em50G uses "push" technology to upload measurement and logger status data to the Decagon Data Service on regular intervals each day. This type of "push" technology allows the Em50G to keep its cellular hardware powered off for most of the time allowing long battery life. The logger uses a unique cryptographic signature and checksum to protect the integrity of the your data as it is transferred over the cellular network and internet as it's uploaded to the Decagon Data Service.

The Em50G keeps track of the data successfully uploaded to the Decagon Data Service. If your logger is unable transfer data during one regularly scheduled session, the data is included in the next upload session.

Once stored in the Decagon Data Service, your measurement data is available for download over the internet. Downloading data does not remove it from the Data Service. It is safely stored for download at any time.

Cellular Service

Decagon makes using the cellular network easy by including the first year of service with the Em50G. Decagon partners with over 200 GSM/GPRS network operators in 120 countries to provide cellular service all over the globe. Decagon has pre-configured your Em50G with an appropriate SIM card for the location where you plan to use your logger. The SIM card and associated service Decagon provides is only for use with the Em50G as outlined by the usage agreement in Appendix C.

NOTE: *Please check with Decagon before moving an Em50G from one country to another to make sure your service plan is appropriate for the new location.*

To extend your service plan or to troubleshoot your cellular service, please contact Decagon or the authorized Decagon Distributor where you purchased your Em50G.

Cellular Coverage

The Em50G requires GSM/GPRS cellular service to upload measurement data to Decagon Data Service. In the USA, the Em50G operates on the T-Mobile and AT&T networks (the Em50G is not compatible with the Verizon or Sprint networks). Outside of the USA, the Em50G should be compatible with technology used by most cellular carriers.

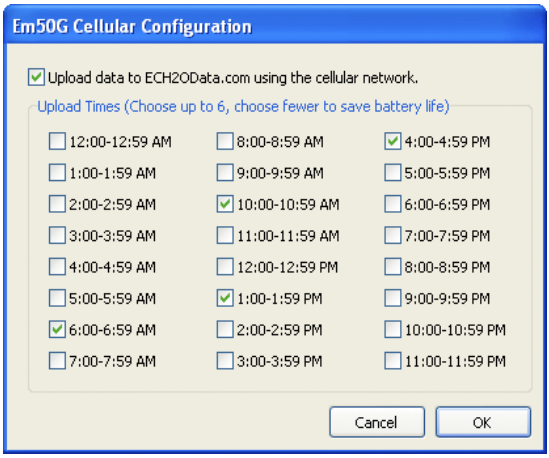
ECH_2O Utility offers a "Communication Test" feature that allows you to evaluate the quality of the cellular network coverage where you plan to install the Em50G. This allows you to evaluate the cellular coverage before installing your logger. Repositioning your logger a short distance may improve your cellular coverage.

For measurement site planning, it may also be useful to consult the network coverage tools offered by each carrier. Please contact Decagon for specific questions about the cellular coverage offered by our partner networks.

In some cases, it may be necessary to use a directional antenna to boost the cellular signal strength of the Em50G to maintain regular data uploads. Please contact Decagon for additional support.

Em50G Configuration and Settings

The Em50G is configured to upload data to Decagon Data Service right out of the box. To start logging and uploading data, configure your logger with the type of sensors installed in each port and turn on sensor logging by choosing a measurement interval. The Em50G will begin uploading data according to the default schedule (uploading between 6-7 AM, 10-11 AM, 1-2 PM, 4-5PM each day).



Use ECH_2O Utility to change these default settings. To turn the cellular network of the Em50G on or off or change the upload times, click the "Configure" button in the "Communication Option" section. The cellular network is active when "Upload data to ECH_2OData.com" box is checked and is off when the box is not checked. In this dialog box, you can choose up to six upload times that correspond to the times when you want to the most up-to-date sensor data available for downloading. The Em50G uses a random time within the hour to reduce resource loads on the cellular network and Data Service. To conserve battery power, choose fewer upload times.

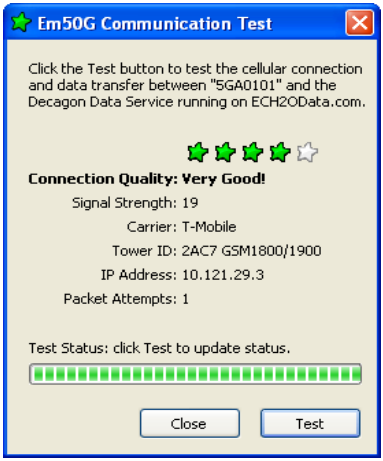
NOTE: *Please contact Decagon if your application requires measuring sensors more often than every 5 minutes or if you need data uploads more often than 6 times a day.*

Click "OK" after making configuration changes. Click "Apply" to save communication settings in your Em50G. Your current settings will show up in the communications option field.

NOTE: *Sensor data recorded by the Em50G while it is configured not to upload data to the Data Service will be stored in the logger, but will not be uploaded to the Data Service. Turning on the upload feature will start uploading data collected on the next measurement interval.*

Communication Testing

ECH_2O Utility helps you check the quality of the cellular communication of your Em50G using the Communication Test feature. Open the Em50G Communication Test dialog by clicking the "Test" button or choosing "Communications Test…" in the Actions menu.



The test takes approximately 30-60 seconds while the Em50G establishes a connection with the cellular network and sends test packets to the Decagon Data Service. Once the tests are finished, the "Connection Quality" field reports connection quality based on cellular signal strength and successful packet transfers. After the initial test is finished, clicking the "Test" button again will update the cellular signal strength and re-send test packets. Subsequent tests are much quicker than the initial test because the Em50G is already connected to the cellular network and the Decagon Data Service. Re-testing your connection quality allows you to find the best spot to install your Em50G. If one test fails, be sure to try the test again.

NOTE: *The cellular radio is on while the "Em50G Cellular Test" dialog window is open. Be sure to close the window when you are done testing to preserve battery power.*

If the connection quality of your Em50G is poor, sometimes moving your logger a short distance will improve the signal

strength. Also consider elevating the antenna by elevating the logger or using an antenna extension cable to improve signal strength. In some cases it may be necessary to use directional antennas to have sufficient cellular signal. Please contact Decagon or your Decagon representative for help choosing the correct antenna for cellular frequencies used at your location.

The Communication Test is checking both the cellular signal strength and the connection to the Decagon Data Service. If the Data Service is temporarily unavailable due internet problems, the connection quality will report a failure even if you have strong cellular signal. If your cellular signal strength is good (above '12') then it is reasonable to expect good connection quality once the Em50G can re-connect to the Decagon Data Service.

NOTE: *The measurement data collected by your Em50G is automatically queued for the next successful connection to the Decagon Data Service. The integrity and continuity of your data is not affected by short term cellular or internet outages.*

Downloading Data

You have two options for downloading the sensor measurement data collected by your Em50G.

Direct Download

Like all Em50 loggers, the Em50G stores more than 36,800 sensor readings for each of the 5 sensor ports. You can use any ECH_2O system software to directly connect to the logger for data download. Your data are always safely stored in non-volatile memory as a backup in unlikely event of data loss on your computer. For downloading instructions when directly connected, see "Downloading Data" in Chapter 4.

Internet Downloading

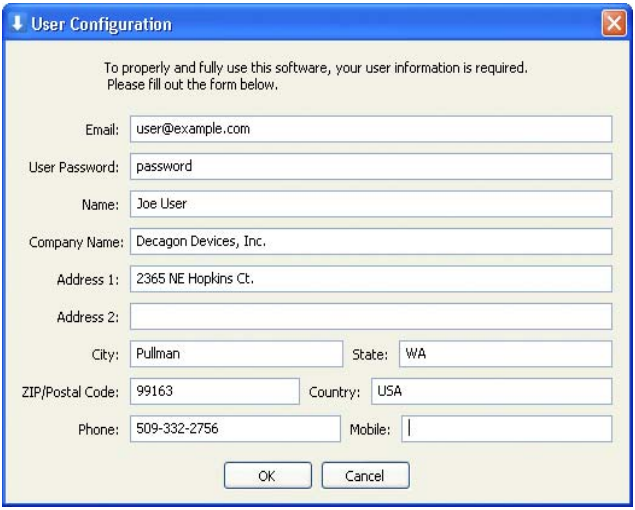
The Em50G and Decagon Data Service make downloading your measurement data over the internet convenient and easy. Use DataTrac 3 to subscribe to data collected by your Em50G. The Em50G WebViewer web application is also designed to download and display Em50G data

NOTE: *ECH_2O Utility does not connect to the Decagon Data Service for downloading data over the internet. You must use either DataTrac 3 or the WebViewer.*

You can choose to use either DataTrac 3, or the free Em50G WebViewer web application, depending on your needs. DataTrac 3 can be installed from the installation CD that came with your logger manual, or you can install the latest version from www.decagon.com/support/downloads/. To access the Em50G WebViewer, go to www.ech2odata.com/viewer/login/. For more information on accessing and downloading data from the Em50G WebViewer application, see the Em50G Web-Viewer Help Files, found by clicking on the "Help" link on the Em50G WebViewer website.

Downloading with DataTrac 3

When you first launch the DataTrac 3 application, you are prompted to enter your user contact information as shown on the screen on the next page.



Decagon uses this information to link you to your subscribed Em50G so that we can provide customer support in the event your logger isn't working as expected. You can update this information at any time by choosing "User Configuration" from the Settings menu. Once you've completed the user information, you are ready to add new subscription information.

In order to download data over the internet for a specific logger, you must first "subscribe" to that Em50G logger. You may subscribe to any number of Em50G loggers. Remember that during the subscription process you must be connected to the internet. To subscribe using DataTrac 3:

1. Click "set-up", "new" and then "Em50 subscription". The following screen will appear.

2. Enter the unique "Device ID" and "Password" for your Em50G. You will find this information on the brightly colored card that came with your Em50G logger. Keep this card in a safe place.

3. Make sure the "Server" option is set to "ECH$_2$OData.com (Default)".

4. Pick the amount of data you want to include in the first download. If this is the first time you are downloading data from this logger, you should choose the "All Data Points" option. If you are only interested in downloading data uploaded over the last day or last week, choose "Last Day" or "Last Week" respectively.

5. Click "OK". DataTrac 3 will communicate with the Decagon Data Service to verify the information you've entered.

Repeat the above steps for each of your Em50G loggers. You can add new logger subscriptions at any time.

Click the "Download" button to download any new measurement data sent by your Em50G loggers since the last time you downloaded. Data files successfully downloaded for each logger is saved in DataTrac 3's auto-import directory (My Documents\

ECH_2O DataTrac\AutoImport\). When DataTrac 3 launches, it will automatically process the files in this directory by appending this data to the appropriate logger.

NOTE: *DataTrac 3 will list loggers in the "New Devices" section by the logger name when it encounters a logger it hasn't seen before. Select your Em50G by its name, and choose the "Configure" button on the DataTrac toolbar. Set the location information if desired, then press "OK".*

Downloading with Em50G WebViewer

For help on downloading data through the Em50G WebViewer web application, please refer to the Em50G WebViewer Help Files, located under the "Help" link on the WebViewer website.

Managing Subscriptions

The DataTrac 3 application attempts to download data from each logger in the main window. If you want to stop subscribing from a logger permanently, select the logger in the list and choose "Delete Subscription" from the File menu.

The Em50G WebViewer also attempts to download data from each of the Em50Gs you have subscribed to. For help on unsubscribing from loggers, see the Em50G WebViewer Help Files, located under the "Help" link on the WebViewer website.

Sharing Data

The Em50G and Decagon Data Service also make it easy to share your measurement data with a colleague or collaborator. You control who has access to specific Em50G data by providing the unique Device ID and Password pair associated with

each logger (found on the brightly colored card shipped with each Em50G).

NOTE: *You should keep the Em50G Device ID and Password card in a safe place. Don't leave it inside the Em50G logger case. Only share the information on the card with people you wish to have access to the data published by your Em50G logger.*

There is no limit to the number of people who can subscribe to each Em50G. Each subscriber either runs their own copy of the DataTrac 3, or uses their own Decagon Data Service account on the Em50G WebViewer web application. One subscriber's data downloads does not interfere with another subscriber's data downloads.

6. Em50R Radio Telemetry

This chapter gives you a brief overview of the radio telemetry available in the ECH_2O system. This information only applies to Em50R. The ECH_2O system supports two types of radio telemetry: "Two-way" modes and "Transmit" modes. Consider one or both types of radio modes when designing your ECH_2O telemetry system. The "Confirm Delivery Transmit" mode ensure the most complete data transfer and the best battery life. However, there are some unique cases where you may want to use the other available modes.

NOTE: *To utilize the radio communication capabilities of the Em50R, you will also need either a DataStation or an Rm-1.*

ECH_2O telemetry networks require each remote radio logger to have a unique name. Each logger leaves the factory with the name set to the logger's unique serial number. You can easily change the name of the logger to help you identify or organize your data. You should not give two loggers the same name. Two loggers with the same name will interfere with each other when communicating over the radio.

Transmit Radio Telemetry

The Transmit Radio modes help you create a simple network of remote radio loggers all transmitting data to a DataStation radio base station. The DataStation stores data from all the remote loggers in one convenient place. Typically, a DataStation is connected to your computer where you can easily download the data for use in DataTrac 3. Unlike the Two-way Radio

modes, you can't remotely change logger settings when using this mode.

When a logger is in Transmit mode, it only turns on the radio when it has new data to broadcast. For example, when you set the measurement interval in your logger to 60 minutes, the logger stores your data every hour and then broadcasts the data to a listening DataStation. The actual transmit time is randomly delayed for several minutes to prevent two or more radio loggers from interfering with each other.

The Transmit radio modes use less battery power because the radio is off most of the time. The Em50R is designed to work approximately 12 months in Transmit mode.

NOTE: *A DataStation is a receiver. It doesn't cause the remote logger to send data. If your DataStation is powered off for some time, it won't receive data sent by the remote loggers. However, the missing data is still stored in the logger. You can directly connect to the logger to download the missing data.*

Transmit Radio Modes

Use the Radio Tab in the logger settings form to choose one of the following radio modes that support Transmit communication.

Confirmed Delivery Transmit: This is the recommended mode since it is the most robust Transmit radio mode. The radio logger adds a checksum to the data packet before broadcasting the data to a DataStation. The logger then waits for the DataStation to confirm it correctly received the data packet. If the logger doesn't hear the confirmation, it retries sending the packet again. The logger stops trying to transmit to a DataStation after 25 attempts.

Transmit Only: This is the original Transmit radio mode. It doesn't offer the advantages of the Confirmed Delivery Transmit mode. You should use the Confirmed Delivery mode when possible. Em5R (discontinued) loggers only support this Transmit radio mode.

Transmit + Two-way and **CD Transmit + Two-way:** These modes combine the Two-way Radio mode and the Transmit Radio mode. You could use these modes while configuring and testing your radio network. You should not leave your radio logger in these modes because they use the most battery power of all the radio modes. Using Transmit + Two-way and CD Transmit + Two-way radio modes with the wake interval set to 1 or 2 will cause the batteries of your logger to drain very rapidly.

Transmit Best Practices

Transmit modes are most useful when you have three or more loggers installed within radio range of each other. There is no set limit to the number of radio loggers broadcasting to a DataStation. Use this mode for as few as one logger and as many as 50 or more loggers. You should use the Telemetry Test feature of ECH_2O Utility to test the connection from your logger to the DataStation.

NOTE: *Em50R loggers must have firmware version 1.12 or later to enable the Confirmed Delivery Transmit mode and Telemetry Test feature. Your DataStation must have firmware version 1.09 or later to receive Confirmed Delivery Transmit mode data packets. Contact Decagon for an application note that covers the steps needed to upgrade your hardware.*

See section on DataStation Networks for step by step instructions for configuring your DataStation and remote radio loggers.

Two-Way Radio Telemetry

The Two-way Telemetry Mode lets you establish a two-way connection with a remote radio logger. Once connected to the remote logger, you can download data and change most settings just like you were connected directly to the logger with a serial cable. Communicating with a remote radio logger requires you to have a Rm1 radio modem connected to your computer. Connecting to the remote radio logger happens through the Rm1.

When a logger is in a Two-way Radio Mode, it turns on its radio every 45 seconds. While the radio is on, the logger listens for connection attempts from a Rm1. If the logger doesn't hear any connection attempts, it turns off the radio. If the logger hears a connection attempt, it leaves the radio on for several seconds listening for login commands from ECH_2O Utility. It takes up to 60 seconds to connect to the remote logger.

When you are finished interacting with the remote radio logger, you press the disconnect button. ECH_2O Utility sends a "logout" command to the remote logger to indicate the end of the communication session. When the remote logger hears the "logout" command, it waits for 10 minutes before listening for additional connection attempts via the radio (you can always direct connect to your logger). This allows you to connect to other loggers with the same radio settings. Otherwise, the first logger you contacted may reconnect. This would prevent you from connecting to your other loggers.

The Two-way modes generally consume the most power. The Em50R is designed to work for several months in the Two-way modes.

Two-way Radio Modes

Use the Radio settings section of ECH_2O Utility to choose one of the following radio modes that support two-way communication.

Two-way 24-hour: The radio logger listens for connection attempts every 45 seconds, 24 hours a day. This mode uses a substantial amount of batter power. Expect batteries to last for approximately 3 months.

Two-way 6:00-18:00: The radio logger listens for connection attempts every 45 seconds between 6 AM and 6 PM. The logger doesn't use the radio between 6 PM and 6 AM to conserve battery power, by not listening for connection attempts during the night. Expect batteries to last for approximately 6 months in this mode.

Transmit + Two-way and **CD Transmit + Two-way**: These modes combine the Two-way Radio modes and the Transmit Radio modes. You could use these modes while configuring and testing your radio network. You should not leave your radio logger in these modes because they use the most battery power of all the radio modes. Expect batteries to last for approximately 3 months in this mode.

NOTE: *Using Transmit + Two-way and CD Transmit + Two-way radio modes with the wake interval set to 1 or 2 will cause the batteries of your logger to drain very rapidly.*

Two-way Best Practices

Two-way modes are most useful when you have a small number (one, two, or three) of remote radio loggers you wish to contact. If you have three or more loggers installed within radio range of each other, consider using one of the Transmit

modes. The Two-way modes also allow you to mount an Rm1 in your vehicle and interact with the remote logger while in radio range.

See section on Connecting via a Radio Modem for step by step instructions for establishing a two-way connection with a remote radio logger.

Radio Settings

For two radio devices to communicate they must share the same radio settings. An Rm1 radio modem can only connect to a remote radio logger with the same radio settings. A DataStation will only receive data from loggers with the same radio settings as the DataStation. Set the Radio Channel to the same value for all the devices on the same network. Set the Radio Sub Channel to the same value for all the devices on the same network.

Radio logger networks with different values set for the Radio Channel use different frequency-hopping sequences, and therefore experience minimal interference between groups. Radio logger networks with the same Radio Channel value but different Radio Sub Channel values can interfere with each other, but can't communicate with each other. This interference can also cause additional battery drain in the radio logger.

The default values for Radio Channel and Sub Channel are zero. Use ECH_2O Utility to choose other values.

Radio Performance

The maximum range of the radio modules in the radio logger and DataStation are affected by the environment, installation

method, and antenna choice. Maximizing the range of your radio network requires you to consider all of these factors.

Buildings, hills, vegetation, vehicles and other environmental obstructions will shorten the radio's range – sometimes drastically. You should ensure a clear, open path between radio devices. Also, radio frequency (RF) interference in the environment around the radio can reduce the usable range (even if not using the same radio frequencies). You should consider nearby growing vegetation when designing and testing your radio network. Some radio networks work fine when the vegetation is sparse, yet may fail when vegetation is full.

You can increase the effective transmit range by maximizing the height above ground of the radio antenna. This helps ensure a clear path for the radio signals and reduces the amount of signal absorbed by the earth. Use an antenna extension cable to help you position your antenna when it isn't practical to install your logger higher off the ground. If you mount your radio logger to a metal pole, you should mount your antenna to the top of the metal pole so it is free to radiate the signal above the pole.

Replacing the stock antenna on your radio device with a high-gain antenna can greatly increase the radio range. Consider using a directional Yagi antenna or a high-gain omni-directional antenna when you want to extend the range of your radio network. A high-gain antenna can also help overcome the effects of unavoidable environmental obstructions.

The ECH_2O telemetry system also supports a simple relay for use with Transmit Mode networks. Combining a relay and high-gain antennas allows radio devices to communicate over

very long distances. Contact Decagon for more information on using a relay in your radio network.

Connecting via Rm-1 Radio Modem

Connecting to an Em50R via a Rm1 is different than connecting via your USB cable. Keep notes concerning the Em50R name and radio settings to make the rest of the system configuration easier to accomplish.

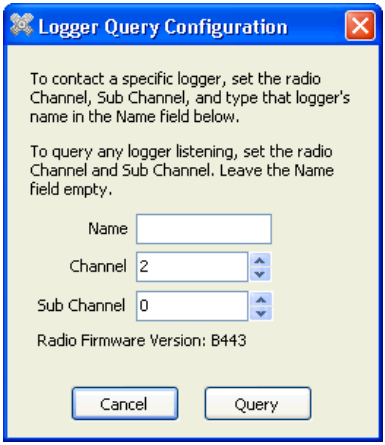
Before you can use the telemetry options of your Em50R, you must configure the Em50R by connecting it directly to your computer using your USB cable. Connect using ECH_2O Utility or DataTrac 3 and set the Em50R's Channel, Sub Channel, and Radio Mode. See the section on Configuring in ECH_2O Utility for additional information on configuring the Em50 series loggers. The Channel can be set from 0 to 6 inclusive (default is 0). The Sub Channel can be set from 0 to 65534 inclusive (default is 0). To use the radio logger with an Rm1, the Radio Mode has to be set to one of the Two-way modes.

If the Two-way 6:00-18:00 mode is chosen, then connection via the Rm1 can only take place between the hours of 6:00 AM through 6:00 PM. This mode was designed to improve battery life by not keeping the radio on constantly. The other Two-way modes can be connected to 24 hours a day.

After setting the Radio Mode, click the "Apply" button in ECH_2O Utility. Disconnect from the Em50R logger. Now, connect your computer to the Rm1 by using a standard 9-pin serial cable. (A USB version of the Rm1 is also available.)

Choose the correct communication port in the "Connect Via" drop-down menu. For example, if your Rm1 is physically con-

nected to your computers COM1 communication port, you would choose "Rm1 on COM1 Communication Port" in the "Connect Via" menu. Click the "Connect" button.



The Logger Query Configuration form will appear. To connect to a specific Em50R, type the logger's Name, Channel, and Sub Channel. After typing the name, click the Query button. If you want to connect to any available Em50R, pick the correct Channel and Sub Channel, but leave the Name field blank.

NOTE: *To connect to a radio logger, the radio Channel setting must be the same for both the logger and the Rm1. The radio Sub Channel setting must also be the same for both the logger and the Rm1.*

The Connection Progress screen appears as ECH_2O Utility tries to establish a radio connection with the remote logger through the Rm1. The connection process can take up to 60 seconds while ECH_2O Utility sends a logger "wake up" signal and retries the connection attempt.

When ECH_2O Utility connects to a remote radio logger, it shows the signal strength of the connection with the radio signal strength icon on the status bar. Click on the radio signal strength icon to see the signal strength percent in the message area.

See Chapter 9: Troubleshooting if ECH_2O Utility fails to connect to your remote logger.

Once ECH_2O Utility establishes a two-way radio connection with a remote logger, you can interact with the logger just like a direct connection.

NOTE: *You cannot change the radio Channel or radio Sub Channel settings in the remote logger while connected via the Rm1.*

DataStation Networks

Configure a DataStation

After establishing a connection set the Channel and Sub Channel. Channel can be set from 0 to 6 inclusive (default is 0). The Sub Channel can be set from 0 to 65534 inclusive (default is 0).

Note the Channel and Sub Channel settings chosen. Click the "Apply" button to save the settings to the DataStation. For easy data downloading and telemetry testing, leave the DataStation plugged into your computer and your powered at all times.

Configure an Em50R Logger for use with the DataStation

To use one or more Em50R loggers with a DataStation the Radio Mode has to be set to one of the Transmit modes. We recommend the "Confirm Delivery" transmit mode.

Connect the Em50R to your computer or handheld device using the appropriate cable. Start ECH_2O Utility, ECH_2O Utility Mobile or DataTrac. Once you're connected, set the radio Channel and Sub Channel settings to exactly the values chosen for the DataStation previously. Set the Radio Mode to Confirmed Delivery Transmit. This mode provides a method for confirming the delivery of the data which greatly increases the ability of the system to successfully transfer the data. The Transmit + Two-way modes are there for use as troubleshooting aids. Set the measurement interval and pick the sensors that will be plugged into each port. See the section on Configuring in ECH_2O Utility for additional details on configuring the Em50 series. After setting the Radio Mode, click the "Apply" button.

NOTE*: ECH_2O Utility only shows the radio modes compatible with your radio logger model and firmware version. If you don't see the "Confirmed Delivery Transmit" radio mode option, then your radio logger may not support this option. If you are using an Em50R logger you will need to update the firmware to version 1.12 or newer. Visit www.decagon.com/support/downloads for the most current firmware and software modes.*

Communication Test

Before finding a permanent location for your Em50R, perform a communication test to verify the quality of the radio communication. However, make sure your DataStation is properly configured and powered during your communication test.

In your field area, connect your Em50R to either a laptop or handheld device using the appropriate cable and press connect. Ensure that your radio channel and subchannel as well as your

transmit mode are the same as your DataStation. Choose "Communication Test" from the Actions Menu.

Click the Test button and the test will begin. When the test has finished you will be presented with the results of the test. Five stars signifies excellent communication. One star means that all of your data are being transmitted, but multiple tries are necessary. The more attempts to send data means more power is used. Therefore, one star is adequate for data transmission, but will decrease battery life.

You may have to relocate the radio logger while doing the Telemetry Test in order to find the best connection quality. Once you have found the radio logger location that provides the best connection quality, install the radio logger at that location.

NOTE: *Communication Test only works with Em50 loggers running firmware 1.12 or newer.*

Download Collected Data

After the DataStation is configured, it will automatically collect data from Em50R loggers within range and sharing the same channel and sub channel. After data is collected, you can retrieve the data for permanent storage and analysis. DataTrac is best suited for this application.

To download and view data from the DataStation, start DataTrac. In the DataTrac menu, pick the DataStation you want to connect to and click "connect." Click the "Download New Data" button. The Downloading DataStation Data screen will appear and provides a progress bar displaying the download progress.

Data Processing

DataTrac automatically sorts the data collected by the DataStation and associates the data with the correct logger. However, unless you used DataTrac to also configure your Em50R loggers, DataTrac will not know your logger's name and which sensors are plugged into each port. To add this information to your data set, click on the appropriate Em50R in the logger tree and select "Configure."

If DataTrac is not an option, ECH_2O Utility can be used to retrieve data from your DataStation. ECH_2O Utility gives you several choices for the file type when downloading data from a DataStation. See Chapter 5: Using ECH_2O Utility, for more information. If you choose processed or raw data file formats, ECH_2O Utility walks you through processing the data for each logger it recorded data for. It prompts you for the logger type and sensor types for each logger. This information is necessary for ECH_2O Utility to process the data correctly.

7. Compatible Sensors

The Em50 logger is only compatible with sensors made by Decagon. This chapter gives a list of compatible sensors. To learn more about individual sensors and their respective calibrations, please visit http://www.decagon.com/support/sensor-calibration-master-list.

Soil Water Content Sensors

10HS, EC-5 High Frequency Soil Moisture
5TM Soil Moisture and Soil Temperature
5TE, GS3, RS3 Soil Moisture, Soil Temperature, Soil EC

Soil Water Potential Sensor

MPS-2 Water Potential and Temperature Sensor

Leaf Wetness Sensor

LWS Leaf Wetness Sensor

Temperature Sensors

ECT Air Temperature Sensor
RT-1 Rugged Soil Temperature Sensor

Rain Gauges Sensors

ECRN-50 Low Resolution Rain Gauge
ECRN-100 High Resolution Rain Gauge

Temperature and Relative Humidity Sensor

EHT Temperature/RH Sensor

Radiation Sensors

PYR Solar Radiation Sensor
QSO-S PAR Photon Flux Sensor

Wind Sensor

Davis Cup Anemometer

Deep Drainage Sensors

G1/G2 Drain Gauge

Irrigation Switch

PS-1 Pressure Switch

Miscellaneous Sensors

ECRN-50 Volume
Millivolt (0-3000 mv input)
Millivolt (0-1500 mv input)
Pulse Counter
Flow Meter

Discontinued Sensors

EC-10, EC-20 Classic Soil Moisture
EC-TM Soil Moisture and Temperature
ECH2O-TE Soil Moisture, Soil Temperature, Soil EC
MPS-1 Dielectric Water Potential Sensor

8. Caring for the Em50

Replacing the Batteries

If installed correctly, the Em50 requires little maintenance. The main requirement is that batteries need to be replaced when their charge becomes too low. When the battery life indicator in ECH_2O Utility shows your Em50's batteries are less than 5%, you need to replace them.

NOTE: *Installing or changing the batteries in your Em50 resets the internal real-time clock. You must connect to your Em50 using any ECH_2O system software to reset the logger's clock immediately after changing the batteries. If you don't set the logger's clock, the time and date associated with each measurement will be incorrect.*

Long-Term Maintenance

When caring for the Em50 over an extended period of time, be sure to do the following periodically:

1. Check the battery holders and make sure they are clean and free of corrosion.
2. Check that the sensor ports are clean, and that the sensors are making good contact with the ports.
3. Check case gaskets and sensor cable strain relief.

9. Troubleshooting

Although the Em50 has been designed for durability and built to the highest manufacturing standards, problems may occasionally occur. This chapter details the most common problems that you may encounter, and their solutions. If you have a problem not described here or that this section cannot remedy, contact Decagon by email at support@decagon.com or call us at at 1-509-332-5600.

Troubleshooting Serial Ports

PROBLEM: The ECH_2O Utility tells me the communication port I want to use is in use by another application, but I don't think any other programs are running.

SOLUTION: Some PDA synchronization programs monitor serial communication ports. Disable Microsoft's ActiveSync or Palm's HotSync system software while trying to use the serial port with the ECH_2O Utility.

PROBLEM: My USB to Serial adapter is not showing in the communication port picker.

SOLUTION: Enable "Force find all Communication Ports" in the Preferences Menu by going to the Edit Menu, clicking Preferences, then the Communication tab, and enabling the check box at the bottom of the screen. Enabling this option may find other serial ports that are not available for use by the ECH_2O Utility (for example, modems installed in your computer).

Troubleshooting DirectConnection

PROBLEM: ECH_2O Utility tells me it can't connect to my device.

SOLUTION: Try one or more of the following to make sure there is a connection to the ECH_2O device:

If you are using the accompanying USB cable, download the USB driver from www.decagon.com/support/downloads. Check your serial port choice. Make sure the "Connect Via" drop-down menu shows the name of the serial port you are using to physically connect to your logger or DataStation. For example, if our logger is physically connected to COM1, the "Connect Via" control should be set to "Direct on COM1 Communication Port".

Check that your serial cable is securely plugged into your logger or DataStation and your Computer.

Make sure your logger has good batteries or your DataStation is plugged in. Try pressing the reset button on your logger or DataStation.

NOTE: *Serial Cables can fail. If you suspect your serial cable may be the problem, try connecting to a second logger. If you can connect, the problem is probably the first logger. If you can't connect to the second logger either, the problem may be your cable. Try using a spare Decagon Serial Cable Adapter or the USB cable if you are having trouble connecting to a logger.*

PROBLEM: ECH_2O Utility keeps reporting it lost the connection to my device.

SOLUTION: This rarely happens for a direct connection. Please check or replace your serial cables. You can also increase the number of times ECH_2O Utility tries sending commands to the logger or DataStation. Increase the Direct Connect Retries on the Communication tab of the Preferences form.

Troubleshooting Radio Connections

PROBLEM: ECH_2O Utility tells me my radio modem isn't responding.

SOLUTION: Make sure your serial cable is securely attached to your computer and your Rm1. Your Rm1 should have power and be turned on.

PROBLEM: ECH_2O Utility tells me it can't connect to my radio logger when I'm using an Rm1.

SOLUTION: Try one or more of the following to make sure there is a good radio connection to your remote logger:

- Make sure your DataStation and Em50R have the same Channel and Subchannel and that the DataStation is being continuously powered.
- Make sure you are within radio range of the remote logger by performing a telemetry test. If this is the problem, increase the radio signal strength to your logger by moving closer to your logger or using a high-gain antenna to see if you can establish a radio connection.
- Make sure the antenna on the logger and the Rm1 are securely fastened to the radio module.

- Check the Radio Channel and the Radio Sub Channel settings you are using on your remote loggers and Rm1. See Chapter 7, Connecting via a Radio Modem, for how to configure your radio settings.
- Make sure you wait ten minutes between connection attempts for the same logger. If you just disconnected from a logger, you must wait for ten minutes before that logger will accept radio connections (you can always direct connect to your logger).
- Make sure your logger has good batteries. Try pressing the reset button on your logger.

PROBLEM: ECH_2O Utility keeps reporting it lost the connection to my device.

SOLUTION: This can happen when the radio connection is lost. Try increasing the radio signal strength by moving closer to the remote logger or using a high-gain antenna. You can also increase the number of times ECH_2O Utility tries sending commands to the logger. Increase the Radio Connect Retries in the Communications tab on the Preferences form.

Troubleshooting Data Issues

PROBLEM: ECH_2O Utility tells me there is no new data for downloading.

SOLUTION: Make sure the logger is configured to measure data. Make sure the measurement interval is set to a number greater than zero. Try pressing the reset button if the logger does have a non-zero measurement interval.

PROBLEM: My sensor data shows "* * *" in the Scan window.

SOLUTION: The three asterisks mean the raw data measured by the logger is out of expected range for the sensor. This could be caused by a broken sensor. Make sure the sensor is fully inserted into the logger's sensor port. Make sure the sensor type shown in the Scan window matches the sensor actually connected to your logger.

PROBLEM: My sensor data doesn't seem to be correct.

SOLUTION: There are many issues that affect the quality of the sensor measurement. Please see the user manual of your particular sensor for help troubleshooting the data collected by your sensor or contact Decagon by phone at 1-509-332-5600 or by email at support@Decagon.com.

Troubleshooting Logger Issues

PROBLEM: My logger stopped making measurements.

SOLUTION: Make sure the measurement interval is not set to 0. The Em50 does not make any measurements when the measurement interval is set to zero.

Try pushing the reset button. Try initializing your Em50 if a reset isn't enough to get the logger measuring sensors again. Connect to the logger and choose "Initialize Device..." from the Device Tools sub-menu in the Actions menu. Initializing your Em50 will erase any stored data so you should download any data you want to keep before choosing this option.

PROBLEM: My logger doesn't seem to be working correctly or reliably.

SOLUTION: Try pressing the reset button on the logger. This resets the logger's firmware. You can also try connecting to the logger and testing the integrity of the firmware. Choose "Test Device Firmware" from the Device Tools menu of the Actions menu. Contact Decagon for help reloading the firmware if ECH_2O Utility reports the device firmware is corrupt. If the firmware tests good and your logger is still not working correctly, please contact Decagon for repair or replacement.

Appendix A:

Em50 CE Compliance

Application of Council Directive:	89/336/EEC
Standards to Which Conformity is Declared:	EN61326 : 1998 EN55022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Ct. Pullman,WA 99163
Type of Equipment:	Data collection system
Model Number:	Em50
Year of First Manufacture:	2002

This is to certify that the Em50, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

Em50R/DataStation/Rm1 CE Compliance

Application of Council Directive: 89/336/EEC

Standards to Which Conformity is Declared: EN61326 : 1998
EN55022 : 1998

Manufacturer's Name: Decagon Devices, Inc.
2365 NE Hopkins Ct.
Pullman, WA 99163

Type of Equipment: Data collection system

Model Number: Em50R 2.4 GHz
Rm1 2.4 GHz,
DataStation 2.4 GHz

Year of First Manufacture: 2002

Restrictions:
France: Current regulations in France stipulate that these devices may be used indoors only. Outdoor use on private property is subject to authorization from the French Telecommunications Regulatory Authority. Outdoor use on public property is currently prohibited. For more information, see www.ero.dk.

FCC Compliance

The following FCC statement applies to the Em50, Em50R, Em50G, DataStation, and Rm1.
This device complies with part 15 of the FCC Rules. Operation is subject to the following conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

The Em50R, DataStation, and Rm1 contain one of the following modules:

FCC ID: OUR9XSTREAM IC: 4214A-9XSTREAM
FCC ID: OUR-24XSTREAM IC: 4214A 12008

The Em50G contains the following module:

FCC ID: IHDT56HQ1 IC: 109O-HQ1

Information for users
Changes or modifications to the EM50 series loggers not expressly approved by Decagon Devices, Inc. could void FCC compliance and thus the user's authority to operate the equipment.

NOTE*:* This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate

radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct th***e*** interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult Decagon Devices or your local representative for support.

Em50G CE Compliance

Application of Council Directive:	89/336/EEC 1999/5/EC
Standards to Which Conformity is Declared:	EN61326 : 1998 EN55022 : 1998
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Ct. Pullman, WA 99163
Type of Equipment:	Data collection system
Model Number:	Em50G
Year of First Manufacture:	2010

Cellular Module Information

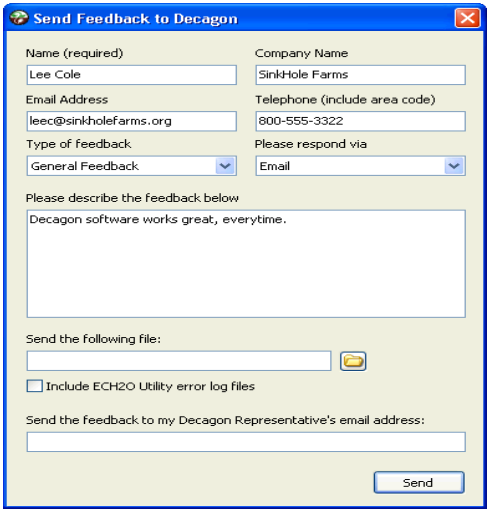
The Quad-band GSM/GPRS cellular module in the Em50G has been tested and approved under the standards and regulations listed below:

FCC part 12,22,24. FCC ID: IHDT56HQ1
Industry Canada (IC) 109O-HQ1
R&TTE - LVD 2006/95/EC
Standards: EN301 489-1 & 7, EN60950
EU Product Approval Number: G24-L
GCF 3.27.1
NAPRD 3.14.0
PTCRB

Appendix B:

Send Feedback to Decagon

Decagon Software makes it easy to send feedback, bug reports, and feature requests to Decagon or your Decagon Distributor. Choose "Send Feedback to Decagon..." from the help menu. This opens the window shown below.



Enter your name, company name, and other contact information. Tell us what type of feedback you are sending (General Feedback, Feature Suggestions, Bug Report, or Other). Indicate how you want us to respond to your feedback (Email or Telephone).

Use the description area to give details for your feedback. If you are reporting a bug, it is very helpful for you to tell us what steps you took for the bug to happen and any error message you saw. By default, bug reports also include the software error files.

You can send Decagon a file using this form too. This is useful for sending data files that you have questions about.

If you work directly with a Decagon representative, put their E-mail address in the field at the bottom of the form. This sends the contents of the form to them. Your Decagon representative can follow-up with you directly.

Appendix C:

Em50G User License Agreement

1. CONTRACT FORMATION

The use of the Em50G ("Device") is governed by the terms and conditions set forth herein. Please read these terms and conditions carefully. If you use or activate the equipment you agree to be bound by these terms and conditions. If you do not accept and agree to be legally bound by these terms and conditions, please do not use the equipment. If you choose not to accept these terms and conditions you may return the Em50G along with all original packaging and accessories for a refund of the purchase price less the cost of shipping and handling.

2. WIRELESS CONNECTIVITY

Decagon provides wireless connectivity for your EM50G for uploading of measurement data and logger status information-under a reseller licensing agreement. You will be charged a fee for wireless connectivity for your use of wireless services on your Device. Decagon reserves the right to discontinue wireless connectivity at any time or to otherwise change the terms for wireless connectivity at any time, including, but not limited to (a) limiting the frequency and amount of data that may be transferred using wireless connectivity and (b) changing the amount and terms applicable for wireless connectivity charges.

3. COVERAGE AND SERVICE INTERRUPTIONS

You acknowledge that if your Device is located in any area without applicable wireless connectivity, you may not be able to use some or all elements of the wireless services. Decagon is

not responsible for the unavailability of wireless service or any interruptions of wireless connectivity.

4. YOUR CONDUCT

You agree you will use the wireless connectivity provided by Decagon only in connection with services Decagon provides for the Em50G. You may not use the wireless connectivity for any other purpose. Unless specifically indicated otherwise, you may not sell, rent, lease, distribute, broadcast, sublicense or otherwise assign any rights to wireless services. You may use the Em50G Software only on the Em50G. You may not sell, rent, lease, lend, distribute or sublicense or otherwise assign any rights to the Software in whole or in part. You may not, and you will not encourage, assist or authorize any other person to, modify, reverse engineer, decompile or disassemble the Em50G or the Software, whether in whole or in part, create any derivative works from or of the Software, or bypass, modify, defeat or tamper with or circumvent any of the functions or protections of the Em50G or Software.

5. AUTOMATIC UPDATES

In order to keep your Software up-to-date, Decagon may automatically provide your Device with updates/upgrades to the Software.

6. EXPORT REGULATIONS

You agree to comply with all export and re-export restrictions and regulations of the Department of Commerce and other United States agencies and authorities, and not to transfer, or encourage, assist or authorize the transfer of the Software to a prohibited country or otherwise in violation of any such restrictions or regulations.

7. GOVERNMENT END USERS

The Software is a "Commercial item" as that term is defined at 48 C.F.R. §2.101, consisting of "Commercial Computer Software" and "Commercial Computer Software Documentation," as such terms are used in 48 C.F.R. §12.212 or 48 C.F.R. §227.7202, as applicable. Consistent with these provisions, the Software is being licensed to U.S. Government end users (a) only as a Commercial item and (b) with only those rights as are granted to all other end users pursuant to the terms and conditions of this Agreement.

8. NO ILLEGAL USE & RESERVATION OF RIGHTS

You may not use the Em50G, or the software for any illegal purpose. You acknowledge that the sale of the Em50G to you does not transfer to you title to or ownership of any intellectual property rights of Decagon or its suppliers. All of the Software is licensed, not sold, and such license is non-exclusive.

9. DATA STORAGE

The Em50G and Software will provide Decagon with data about your Device and its interaction with the software and information related to the content on your Em50G may be stored on servers in the United States at Decagon headquarters. You agree to assume sole responsibility to backup and store your data collected by the Em50G and Software.

10. Data Security and Privacy

While the Em50G and Software use cryptographic methods to protect the integrity of data transfers, Decagon does not guarantee privacy of measurement data or Device status information collected and transferred by the Em50G. You are solely responsible for the security of the Device access passwords issued to you by Decagon.

11. PATENTS

The Em50G and/or software used in association with the Em50G may be covered by one or more patents or pending patent applications, and/or copyright and trademarks or pending applications.

12. TERMINATION

Your rights under this Agreement will automatically terminate without notice from Decagon if you fail to comply with any term of this Agreement. In case of such termination, you must cease all use of the Software and Decagon may immediately revoke your access to the Service or to Digital Content without notice to you and without refund of any fees. Decagon's failure to insist upon or enforce your strict compliance with this Agreement will not constitute a waiver of any of its rights. You may terminate the service at any time, but you will be responsible for all payments under the data services through the end of the term.

13. DISCLAIMER OF WARRANTIES

YOU EXPRESSLY ACKNOWLEDGE AND AGREE THAT USE OF THE EM50G, SOFTWARE AND DATA STORAGE IS AT YOUR SOLE RISK. *EXCEPT FOR THE ONE-YEAR LIMITED WARRANTY,* THE EM50G, SOFTWARE AND DATA STORAGE ARE PROVIDED "AS IS" WITH ALL FAULTS AND WITHOUT WARRANTY OF ANY KIND AND DECAGON AND ITS SUPPLIERS AND LICENSORS DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY, QUIET ENJOYMENT AND NON-INFRINGEMENT OF THIRD-PARTY RIGHTS. NO ORAL OR WRITTEN INFORMATION OR ADVICE GIVEN BY DECAGON OR AN AUTHORIZED REPRESENTATIVE OF DECAGON SHALL CRE-

ATE A WARRANTY. THE LAWS OF CERTAIN JURISDICTIONS DO NOT ALLOW THE DISCLAIMER OF IMPLIED WARRANTIES.

14. LIMITATION OF LIABILITY

LIMITATION OF LIABILITY TO THE EXTENT NOT PROHIBITED BY LAW, NEITHER DECAGON NOR ITS SUPPLIERS OR LICENSORS SHALL BE LIABLE TO YOU FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR BREACH OF ANY EXPRESS OR IMPLIED WARRANTY, BREACH OF CONTRACT, NEGLIGENCE, STRICT LIABILITY OR ANY OTHER LEGAL THEORY RELATED TO THE EM50G, SOFTWARE AND DATA STORAGE, INCLUDING, BUT NOT LIMITED TO, ANY DAMAGES ARISING OUT OF LOSS OF PROFITS, REVENUE, DATA OR USE OF THE EM50G OR SOFTWARE OR ANY ASSOCIATED PRODUCT, EVEN IF DECAGON HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN ANY CASE, DECAGON'S AGGREGATE LIABILITY UNDER THIS AGREEMENT SHALL BE LIMITED TO THE AMOUNT ACTUALLY PAID FOR THE DEVICE. THE LAWS OF CERTAIN JURISDICTIONS DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES.

15. WASHINGTON LAW APPLIES

The laws of the state of Washington, without regard to principles of conflict of laws, will govern this Agreement and any dispute of any sort that might arise between you and Decagon.

16. DISPUTE RESOLUTION

By using the Em50G you agree to jurisdiction and venue of any dispute arising out of this agreement by the Whitman County Court unless the parties agree to a different dispute resolution process in writing.

17. SEVERABILITY

If any term or condition of this Agreement shall be deemed invalid, void, or for any reason unenforceable, that part shall be deemed severable and shall not affect the validity and enforceability of any remaining term or condition.

18. AMENDMENT

Decagon reserves the right to amend any of the terms of this Agreement at its sole discretion by sending an amended agreement in writing to you by first class mail or email. Your continued use of the Device and Software after the effective date of any such amendment shall be deemed your agreement to be bound by such amendment.

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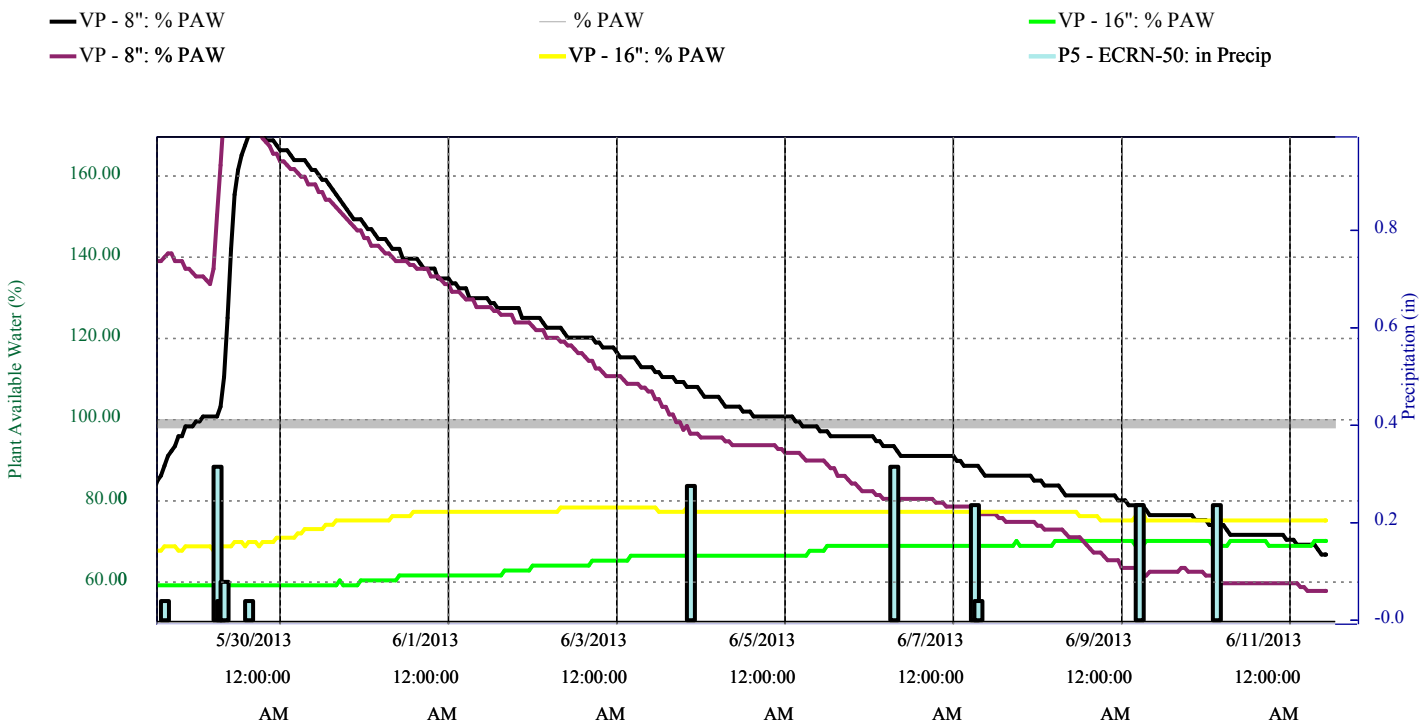
Appendix D

Example Ech2o Report

K22_13

Location: (Grower name)
Start: 5/28/2013 12:52:00 PM
Stop: 6/11/2013 12:52:00 PM



	P5 - in Precip ECRN-50	VP1 % PAW	VP2 % PAW	VP3 % PAW	VP4 % PAW
Avg:	n/a	106.90	65.62	102.63	75.77
Min:	n/a	66.79	59.21	57.83	67.75
Max:	n/a	171.21	70.14	179.67	78.37
Total:	1.85	n/a	n/a	n/a	n/a
Events:	11	n/a	n/a	n/a	n/a

Appendix E

Example Soil Moisture Report

AGRIMANAGEMENT® INC.
AGRICULTURAL CONSULTANTS
408 N. 1st St.
Yakima, WA 98901
Tel: (509) 453-4851
Fax: (509) 588-1672
Web: agrimgt.com

AGRIMETRIC SERVICES – MEASURING CROP NEEDS FOR GREATER PROFITS

Soil Moisture Report

FieldID: Home CP
Crop: Silage Corn
Stage: Avg Height 27"

Acres: 152.6
Irr: Center Pivot
Color: Normal Green

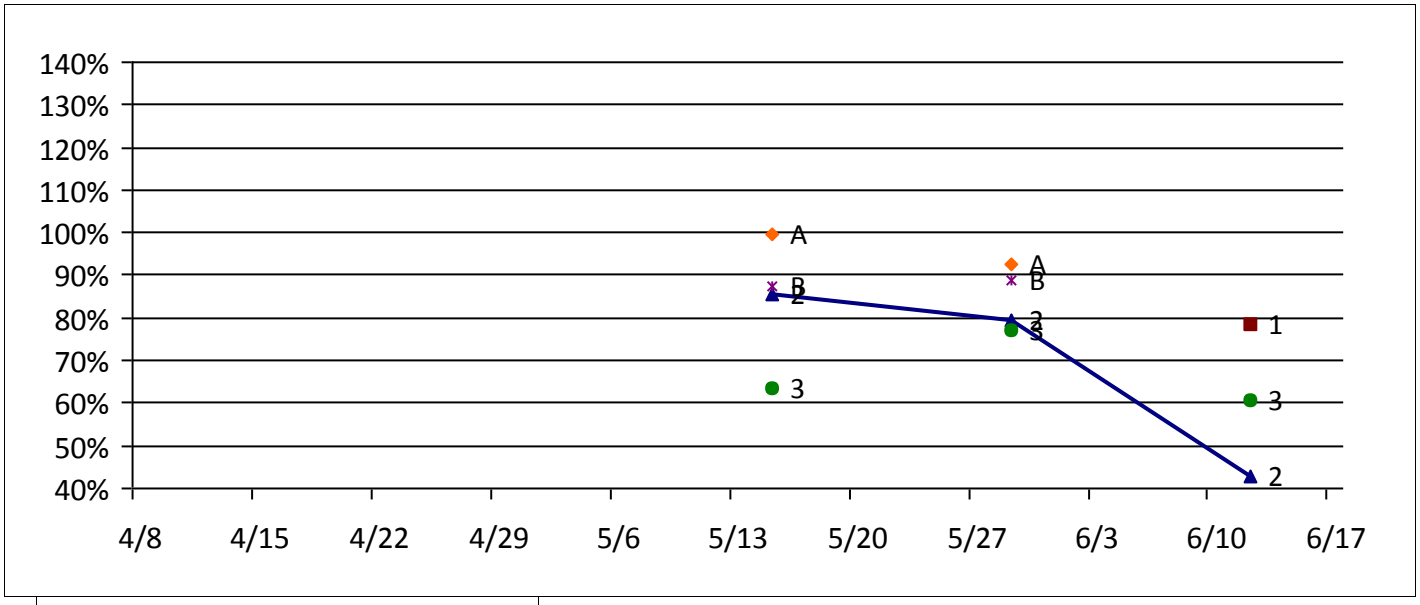
4071 I13-0652
Y

Sample Date: 6/12/2013
Sampler: Ollard
Field Bio: SS: North of pivot

Grower Name
Grower Address

Irrigation Outside Sample Strip Sampled Inside Sample Strip

Comments: System ON NE of pivot - sampled on a hill NW of pivot. Canopy at 70%; height is 24-30". Recently dammer-diked. No weeds present.



Sample Strip

Depth	% AW
1'	79%
2'	43%
3'	61%

Sample Strip
2.74 in. depletion in ASD
1.18 in. depletion in ERD

Avg Sampling Depth (ASD):	3.0
Effective Rooting Depth (ERD):	1.5
Projected Daily Consumptive Use (DCU):	0.20
Projected Weekly Consumptive Use:	1.4
Rain Gauge AVG:	1.50

This field is also trending downward following the recent dammer-diking. Suggest you could now plan to apply up to 1.7"/week this next week to meet plant need and some deficit and possibly a further increase the following week, if the weather is warm. Thanks, Scott.

Est. Recheck Date: 6/26/2013

Reviewed By: Scott Stephen
(509) 949-8843

Appendix F

NRCS Conservation Practice Standards

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

IRRIGATION SYSTEM, SPRINKLER

(Ac.)

CODE 442

DEFINITION

An irrigation system in which all necessary equipment and facilities are installed for efficiently applying water by means of nozzles operated under pressure.

PURPOSE

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

- Efficiently and uniformly apply irrigation water to maintain adequate soil water for the desired level of plant growth and production without causing excessive water loss, erosion, or water quality impairment.
- Climate control and/or modification.
- Applying chemicals, nutrients, and/or waste water.
- Leaching for control or reclamation of saline or sodic soils.
- Reduction in particulate matter emissions to improve air quality.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

The sprinkler method of water application is suited to most crops, irrigable lands, and climatic conditions where irrigated agriculture is feasible. Areas must be suitable for irrigation or sprinkler water application and have an adequate supply of suitable quality water available for the intended purpose(s).

This standard applies to the planning and design of the overall water application through sprinkler discharge systems. This standard pertains to the planning and functional design of all sprinkler components except for special structures, such as permanently installed main and lateral pipelines or pumping plants. Other components shall meet appropriate NRCS Conservation Practice Standards.

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

CRITERIA

General Criteria Applicable to All Purposes

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

Each sprinkler discharge system must be designed as an integral part of an overall plan of conservation land use and treatment for the intended purpose(s) based on the capabilities of the land and the needs of the operator. The selected system shall be based on a site evaluation, expected operating conditions and verification that soils and topography are suitable for the intended purpose(s).

Depth of Application. Net depth of application shall meet criteria for the intended purpose, not exceeding the available soil water holding capacity and meeting the land user's management plan for the intended purpose.

Capacity. The sprinkler irrigation system shall be designed with adequate capacity to accomplish the primary purpose(s) of the system.

Design Application Rate. Rates shall be selected such that runoff, translocation, and unplanned deep percolation are minimized.

Additional conservation measures, such as furrow diking, dammer diking, in-furrow chiseling, conservation tillage or residue

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your Natural Resources Conservation Service State Office or visit the Field Office Technical Guide.

management shall be applied as needed and appropriate.

Distribution Patterns, Nozzle Spacing and Height. A combination of sprinkler spacing, nozzle size, and operating pressure that provides the design application rate and distribution shall be selected.

Coefficient of Uniformity (CU) data or distribution uniformity (DU) shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. Definitions of each of these uniformity values can be found in the NRCS National Engineering Handbook, Part 652, Irrigation Guide.

Pipelines. The design of main lines, submains, and supply lines shall insure that required water quantities can be conveyed to all operating lateral lines at required pressures. For detailed criteria, see NRCS Conservation Practice Standard, Irrigation Pipeline (430).

Pump and Power Unit. Where required, pump and power units shall be adequate to efficiently operate the sprinkler system at design capacity and total dynamic head. For detailed criteria, see NRCS Conservation Practice Standard, Pumping Plant (533).

Management Plan. An Irrigation Water Management plan, meeting NRCS Conservation Practice Standard, Irrigation Water Management (449), shall be developed for this practice, unless the purpose of the practice is waste water application. Where implemented for waste application, as a component of a Comprehensive Nutrient Management Plan (CNMP), a waste utilization plan and/or nutrient management plan shall be developed that meets the requirements of NRCS Conservation Practice Standards, Waste Utilization (633) and Nutrient Management (590), as appropriate.

Additional Criteria Applicable to Center Pivot or Linear-Move Sprinkler Systems

Design Capacity. Sprinkler systems shall be designed to have the capacity to meet the primary purpose. For the purpose of crop irrigation, sprinkler irrigation systems shall have either (1) a design capacity adequate to meet peak water demands of all irrigated crops in the design area, or (2) adequate capacity to meet requirements of selected irrigations during critical crop growth periods when less than full irrigation is planned.

In computing capacity requirements, allowance must be made for reasonable application water losses.

Distribution Patterns, Nozzle Spacing and Height. Pivot system (Heermann-Hein) or Linear (Christensen) CU shall not be less than 85% (76% DU), except as noted in criteria for a Low Energy Precision Application (LEPA) system. In lieu of the manufacturer's CU information, simulation modeling shall use Agricultural Research Service model Center Pivot Evaluation and Design (CPED) or similar modeling software. Manufacturer's information on nozzle packaging, allowing exclusion of the end gun and the first 12 percent of pivot length, not to exceed 250 feet, shall be considered acceptable documentation of system CU.

In the absence of CU data, sprinkler performance tables provided by the manufacturer shall be used in selecting nozzle size, operating pressure, and wetted diameter for the required sprinkler discharge. To the extent possible, low pressure spray nozzles shall be at uniform heights along the length of the lateral, with the exception of height adjustment to increase wetted diameter for runoff control. From a point midway between the first and second tower to the distal end of a center pivot, spray nozzle spacing along lateral lines shall not exceed 25% of the effective wetted diameter and impact sprinkler spacing shall not exceed 50 percent of the effective wetted diameter. The effective wetted diameter shall be determined from manufacturer's information for the nozzle height.

Lower elevation nozzle application systems, typically less than 7 feet from ground surface, that discharge water in the crop canopy for a considerable length of time during the growing season shall also meet the criteria of a Low Pressure in Canopy (LPIC) system as defined in this standard.

Additional Criteria Applicable to LEPA and Low Elevation Spray Application (LESA) Center Pivot or Linear-Move Sprinkler Systems

Distribution Patterns. For center pivot systems, nozzle discharge CU using the Heermann-Hein weighted area method shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. Nozzle

discharge CU shall not be less than 94% of the calculated design flow rate needed at the discharge point. For linear systems, discharge shall be based on equivalent unit areas.

Nozzle Spacing. Nozzle spacing shall not be greater than two times the row spacing of the crop, not to exceed 80 inches.

Specific Additional Criteria for LEPA

Discharge Height. Water shall discharge through a drag sock or hose on the ground surface, or through a nozzle equipped with a bubble shield or pad at a uniform height not to exceed 18 inches.

Row Arrangement and Storage. LEPA systems are only applicable on crops planted with furrows or beds. LEPA systems shall have row patterns that match the lateral line movement (i.e., circular for center pivots). Water shall not be applied in the tower wheel track of a LEPA system. Runoff and translocation under LEPA systems shall be eliminated by providing surface basin storage such as furrow dikes, dammer dikes, or implanted reservoirs.

Slope. The slope for a LEPA system shall not exceed 1.0 percent on more than 50 percent of the field.

Systems that utilize bubble pads or shields, or drag hoses for a portion of the crop year and then spray nozzles at uniform height not exceeding 18 inches for a portion of the crop year shall meet LESA criteria.

Specific Additional Criteria for LESA

Discharge Height. LESA Systems shall discharge water through a spray nozzle at uniform heights not to exceed 18 inches.

Row Arrangement and Storage. LESA Systems are applicable on crops flat planted, drilled, or planted with furrows or beds. LESA Systems should employ some method of providing surface basin storage such as furrow dikes, dammer dikes, or implanted reservoirs, or farming practices such as conservation tillage, in-furrow chiseling, and/or residue management to prevent runoff.

Land Slope. The slope for LESA systems shall not exceed 3.0 percent on more than 50 percent of the field.

Additional Criteria Applicable to LPIC and Mid Elevation Spray Application (MESA) Center Pivot or Linear-Move Sprinkler Systems

Systems that utilize bubble pads or shields or drag hoses for a portion of the crop year and spray nozzles for a portion of the crop year not meeting all of the LEPA or LESA criteria shall meet LPIC criteria.

Distribution Patterns, Nozzle Spacing and Height. For row crops, when nozzles operate in canopy for 50 percent or more of the growing season, nozzle spacing shall not exceed every other crop row. In-canopy heights shall be such that areas of high leaf concentration are avoided (i.e., corn near the ear height (approximately 4 feet)). Local research and Extension Service information with applicable crops may serve as a guide for establishing appropriate nozzle spacing, height, and row arrangement.

CU (Heermann–Hein CU for center pivots) shall not be less than 90% for all LPIC and MESA Systems with nozzle heights less than 7 feet.

CU shall not be less than 85% (76% DU) for MESA Systems with nozzle heights 7 feet or greater.

Land Slope. The slope for LPIC and MESA systems shall not exceed 3.0 percent on more than 50 percent of the field for fine textured soils and not exceed 5 percent on more than 50 percent of the field on coarse textured soils.

Additional Criteria Applicable to Fixed-Solid-set, Big Gun and Periodic Move Sprinkler Systems

Design Capacity. Sprinkler irrigation systems 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) adequate capacity to meet requirements of selected water applications during critical crop growth periods when less than full irrigation is planned. In computing capacity requirements, allowance must be made for reasonable application water losses.

Design Application Rate. The design application rate shall be within a range established by the minimum practical application rate under local climatic conditions, and the maximum application rate consistent with soil intake rate, slope, and conservation

practices used on the land. If two or more sets of conditions exist in the design area, the lowest maximum application rate for areas of significant size shall apply.

Lateral Lines. Unless pressure reducers or regulators are installed at each outlet, or other pressure compensating or flow control devices are used, lateral lines shall be designed so that the pressure variation or flow variation at any sprinkler, resulting from friction head and elevation differential, does not exceed 20 percent of the design operating pressure or 10 percent of the design flow of the sprinklers, respectively.

Distribution Patterns and Spacing. A combination of sprinkler spacing, nozzle size, and operating pressure that provides the design application rate and distribution shall be selected.

If available, CU (or DU) data shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. CU shall not be less than the following:

- 75 % (60% DU) for deep-rooted (4 feet or more) field and forage crops where fertilizers and pesticides are not applied through the system.
- 85 % (76% DU) for high-value or shallow-rooted crops and for any crop where fertilizer or pesticides are applied through the system.

In the absence of CU data, maximum lateral and nozzle spacing shall comply with the following criteria:

1. For low (2-35 pounds/square inch (psi))-, moderate (36-50 psi)-, and medium (51-75 psi)-pressure sprinkler nozzles, the spacing along lateral lines shall not exceed 50 percent of the wetted diameter, as given in the manufacturer's performance tables, when the sprinkler is operating at design pressure. The spacing of laterals along the main line shall not exceed 65 percent of this wetted diameter.

If winds that can affect the distribution pattern are likely during critical crop growth periods, spacing should be reduced to 60 percent for average velocities of 1 to 5 miles per hour (mph), to 50 percent for average velocities of 6 to 10 mph, and to 45 percent for average velocities greater than 10 mph.

2. For high-pressure and big gun type sprinklers (>75 psi), the maximum distance (diagonal) between two sprinklers on adjacent lateral lines shall not exceed two-thirds of the wetted diameter under favorable operating conditions

If winds that can affect the distribution pattern are likely during critical crop growth periods, the diagonal spacing should be reduced to 50 percent of the wetted diameter for average velocities of 5 to 10 mph and to 30 percent for average velocities greater than 10 mph. Guidance for towpath spacing of travelers in NRCS National Engineering Handbook (NEH), Part 623, Chapter 11, Sprinkler Irrigation, Table 11-31.

3. Sprinkler spacing requirements for orchards, including subtropical fruits:

a) Triangular pattern. The spacing along lateral lines shall not exceed 65 percent of the effective wetted diameter. The spacing of laterals along the main line shall not exceed 70 percent of the effective wetted diameter.

b) Square or rectangular pattern. The nozzle spacing along the lateral and the lateral spacing along the main line shall not exceed 65 percent of the effective wetted diameter at the design operating pressure.

c) Spacing between sprinklers and lateral lines shall be reduced by 2.5 percent for each mph over 3 mph average wind velocity normally occurring during planned hours of operation.

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

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

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

Additional Criteria Applicable to Traveling Sprinkler Irrigation Systems

The towpath spacing shall follow the recommendations in NEH, Part 623, Chapter 11, Sprinkler Irrigation, Table 11-31.

Additional Criteria Applicable to Climate Control and/or Modification

Design Capacity. For temperature control, the sprinkler irrigation system shall have sufficient capacity to satisfy the evaporative demand on a minute-by-minute basis throughout the peak use period. NEH, Part 623, Chapter 2, Irrigation Water Requirements, contains guidance on using sprinkler irrigation systems for temperature control.

For frost protection, the system shall be capable of applying the necessary rate, based on the minimum temperature, maximum anticipated wind speed, and relative humidity, in a uniform manner. The capacity shall be sufficient to supply the demand for the entire crop being protected. NEH, Part 623, Chapter 2, Irrigation Water Requirements, contains guidance on using sprinkler irrigation systems for frost protection.

Additional Criteria Applicable to Chemical, Nutrient and/or Waste Water Application

The installation and operation of a sprinkler irrigation system for the purpose of chemical or nutrient application (chemigation) shall comply with all federal, state and local laws, rules and regulations. This includes backflow and anti-siphon prevention measures. Additionally, surface waters shall also be protected from direct application.

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

Sprinkler irrigation systems used to apply waste shall be designed with sprinkler nozzles of sufficient size to prevent clogging. Treatment of the wastewater using solid separators, two stage lagoons, two-stage waste holding ponds, etc., may be needed to reduce percent solids.

Design Application Rate and Timing. Application rates shall meet the levels specified in General Criteria. Timing of chemical applications shall be the minimum length of time it takes to deliver the chemicals and flush the pipelines at rates specified by the label.

Coefficient of Uniformity. If available, CU (or DU) data shall be used in selecting sprinkler spacing, nozzle size, and operating pressure. The CU shall not be less than 70% for wastewater and not less than 85% (76% DU) for chemigation or fertigation. If CU data is not available, distribution patterns and spacing requirements shall be in keeping with the appropriate specific criteria of this standard.

Nutrient and Pest Management. Chemicals, fertilizers and liquid manure shall be applied in accordance with appropriate NRCS Conservation Practice Standards, Nutrient Management (590), Pest Management (595), Waste Utilization (633), and Manure Transfer (634). Chemical or nutrient application amounts shall not exceed these standards.

NEH, Part 623, Chapter 2, Irrigation Water Requirements, contains guidance on using sprinkler irrigation systems for chemigation.

Additional Criteria Applicable to Leaching

Design Application Rate and Depth. Application rates shall meet the levels specified in General Criteria. Design depth shall be determined as defined in NEH, Part 623, Chapter 2, Irrigation Water Requirements.

Management or Reclamation Plan. A plan shall be developed conforming to the requirements contained in NRCS Conservation Practice Standard, Salinity and Sodic Soil Management (610).

Additional Criteria Applicable to Reduction in Particulate Matter Emissions to Improve Air Quality

These criteria pertains to sprinkler systems used to improve air quality by controlling dust emissions from confined animal pen areas and other critical areas such as unpaved roads, staging areas, and equipment storage yards.

Installation of fixed solid set sprinklers or periodic move sprinkler systems for dust control shall conform to the criteria stated

above, unless described by criteria in this section. The installation and operation of Sprinkler Systems for dust control on confined animal pen areas shall provide application coverage on the majority of pen areas occupied by livestock, except for feed bunk aprons. The quality of discharge water shall be pathogen free and fit for animal consumption.

Capacity and Application Rate. For dust control, the sprinkler irrigation system shall have sufficient capacity and operational flexibility to apply the design application depth every three days or less. When determining capacity requirements, allowance shall be made for reasonable water losses during application.

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

Open-lot management practices shall be applied that include scraping and removal of manure in pens between occupations, and shaping of the holding areas to prevent water ponding and chronic wet areas.

Over-application and excessive sprinkler overlap shall be avoided to minimize runoff and reduce odor and fly problems.

Water Amendments. Appropriately labeled chemicals for pest control or dust suppression may be applied through the sprinkler system when designed, installed and operated with appropriate backflow prevention and anti-siphon devices. When chemicals are applied through the sprinkler system, surface waters and livestock watering facilities shall be protected from direct application unless chemical labels indicate that direct application will not negatively impact animal health or water quality.

Distribution Patterns and Spacing. A combination of sprinkler spacing, nozzle size, and operating pressure that provides the design application rate and distribution pattern shall be selected.

Maximum spacing of sprinklers along laterals shall not be greater than 75 percent, and no closer than 50 percent of wetted diameter listed in manufacturer's performance tables.

Spacing between lateral shall comply with the following criteria:

1. For medium (51-75 psi)-pressure sprinkler nozzles, the spacing of laterals along the main line shall be no more than 90 percent, and no closer than 70 percent of wetted diameter.

2. For high-pressure sprinklers (>75 psi), the maximum distance between two sprinklers on adjacent lateral lines shall not exceed 100% of wetted diameter.

If winds impact distribution patterns during critical dust emission periods, the system shall be equipped with timer overrides and have the flexibility to be operated manually during periods of lesser wind, such as late evening and early morning.

Risers. Riser pipes used in lateral lines shall be high enough to minimize interference with the distribution pattern. The risers shall be constructed in a manner that provides protection from corrosive soils, equipment damage, and livestock damage. Riser heights shall place the discharge sprinkler not less than 6 feet above ground surface. Risers shall be anchored and stabilized.

System Valves and Controllers. Due to high application rates inherent with large sprinkler nozzle diameters, an automatic irrigation control system shall be utilized for all nozzles greater than 0.5 inch diameter. The automated control system shall utilize electro-hydraulic valves facilitating automatic operation. The valves shall be of a size and quality consistent with standard engineering practice. The operating system shall provide the flexibility to change sprinkling duration in one-minute increments and have a minimum of six start times per-day to provide for adjustment for climate conditions.

Systems shall be equipped with a rain sensor connected to the control valve network set to prohibit system operation during rainfall events.

Manual zone isolation valves shall be incorporated to isolate laterals allowing partial system operation during periods of maintenance and repair.

In areas of uneven or sloping terrain a control valve or low-head drainage device shall be incorporated at each sprinkler to ensure that

line drainage to the lowest sprinkler is minimized.

Additional Criteria Applicable to Reduce Energy Use

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

Reduction of energy use is calculated as average annual or seasonal energy reduction compared to previous operating conditions.

CONSIDERATIONS

When planning this practice the following items should be considered, where applicable:

Application rates near the end of a center pivot may exceed soil intake rate. Light, frequent applications can reduce runoff problems, but may increase soil surface evaporation. Nozzle offsets or booms can be used to reduce peak application rates.

For low suspended nozzle application systems, row arrangement, nozzle spacing, discharge nozzle type and configuration, along with height all impact CU. System design and field management should complement each other to yield the highest CU. In general, circular rows for center pivot systems and straight rows for linear move systems provide higher CU's.

Some aspects of non-uniformity tend to average out throughout the irrigation season while others tend to accumulate. Factors that tend to average out during the irrigation season are climatic conditions and uneven travel speed for systems that start and stop. Factors that tend to accumulate during the irrigation season are nozzle discharge variances due to pressure or elevation differences, surface movement of water, and poor water distribution around field boundaries.

Consider the effects of a center pivot end gun operation on CU. A large end gun may reduce the average CU by 1 percent for each 1 percent of the area covered past the main system hardware.

Consider the on and off effects of center pivot corner arm units and end guns on overall sprinkler performance. Discharges reduce flow in the main tower, significantly lowering the CU.

Beneficial effects of conservation practices applied to limit surface redistribution of water and runoff may diminish over the irrigation season.

The velocity of prevailing winds and the timing of occurrence should be considered when planning a sprinkler system. Systems designed to operate in varied time increments aid in balancing the effects of day and night wind patterns.

Consider filtering or screening the irrigation water before it enters the system if it contains particulate matter, algae, or other material that could plug the sprinkler nozzles.

Drop tubes should be installed alternately on both sides of the mainline and when used in-crop they should have a flexible joint between the gooseneck pipes and the application device. Drops should be weighted or secured in windy areas.

Consider different sprinkler application depths and application rates with hand move and center pivot systems. With hand move systems, the application rates more nearly match the soil infiltration rate so that large irrigations can be applied and the number of hand moves reduced. With an automated system, such as a center pivot, hand labor is not a major consideration and small applications at high rates are normal.

Fertilizer and chemical application amounts may vary from prior application methods and rates, due to precise applications possible with some sprinkler irrigation systems.

Management of sprinkler irrigation systems normally include utilizing soil water stored in the root zone, especially during critical crop growth stages.

Deflection of spans on center pivots and linear-move systems is common when the lateral is loaded (filled with water). This should be considered when determining nozzle heights. Wheel track depth will also affect nozzle height.

Water distribution is greatly affected by nozzle spacing and height for LPIC and MESA systems. In general, smaller, more closely spaced nozzles will yield a higher uniformity than larger, more widely spaced nozzles.

On center pivot or linear move systems, nozzles should be diverted away from wheel tracks to avoid rutting.

Low pressure systems (35 psi or less) are sensitive to small changes in nozzle pressure. Consider using pressure regulators on all low pressure systems where elevation differences, pumping depth variations, and end gun or corner arm operation can significantly change nozzle discharge and sprinkler uniformity. Also consider installing a pressure gauge at both ends of the sprinkler system to monitor system pressure.

Consider system effects on the water budget, especially the volume and rate of runoff, infiltration, evaporation, transpiration, deep percolation, and ground water recharge.

Consider system effects on erosion and movement of sediment, and soluble and sediment-attached substances carried by runoff.

Consider system effects on soil salinity, soil water or downstream water quality including subsurface drains. Crops may be more sensitive to salts applied to plant foliage during sprinkling than to similar water salinities applied by surface irrigation, subirrigation, and microirrigation. Information on foliar injury from saline water applied by sprinkler irrigation is contained in NEH, Part 623, Chapter 2, Irrigation Water Requirements. If the salt content of the irrigation water is high, other irrigation methods should be considered.

Where wastewater is used for irrigation, timing of irrigation based on prevailing winds should be considered to reduce odor. In areas of high visibility, irrigating at night should be considered. The use of wastewater may reduce the life of the system due to corrosion or abrasion.

When utilized for particulate matter reduction, check to assure adequate animal feeding operation water supplies are available to meet other operating needs, during sprinkler system operation.

Irregularly shaped pen areas that are impractical to treat with a sprinkler system and where potential dust sources may occur should be treated for dust control with tanker water trucks equipped with hoses, or nozzles designed to apply water at rates similar to an equivalent sprinkler system.

Open-feedlot management practices that minimize thickness of loose manure will reduce water demands for dust control, as well as, reduce wet areas and ponding that could increase ammonia emissions.

PLANS AND SPECIFICATIONS

Plans and specifications for constructing irrigation sprinkler systems shall be in keeping with this standard and shall describe the requirements for properly installing the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An operation and maintenance plan must provide specific instructions for operating and maintaining the system to insure that it functions properly. It should also provide information regarding periodic inspections and prompt repair or replacement of damaged components. The plan, at minimum, shall include provisions to address the following:

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

REFERENCES

USDA-NRCS, National Engineering Handbook, Part 623, Chapter 2, Irrigation Water Requirements.

USDA-NRCS, National Engineering Handbook, Part 623, Chapter 11, Sprinkler Irrigation.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

IRRIGATION SYSTEM, SURFACE AND SUBSURFACE

(Ac.)

CODE 443

DEFINITION

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

PURPOSE

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

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

CONDITIONS WHERE PRACTICE APPLIES

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

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

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

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

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

CRITERIA

General Criteria Applicable to All Purposes

Conservation irrigation methods. All irrigation systems must be designed as an integral part of an overall plan of conservation land use and treatment for the farm which is based on capabilities of the land and needs of the irrigated area.

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

Capacity. The irrigation system shall have adequate capacity to meet the intended purpose(s).

If more than one irrigation method will be used on the same field, the system capacity shall be adequate for the method requiring the highest water delivery rate.

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your Natural Resources Conservation Service State Office or visit the Field Office Technical Guide.

All structures and water delivery components shall be designed for maximum flow conditions expected and shall have adequate capacity and/or freeboard.

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

Additional Criteria Applicable to Surface Irrigation Systems

Design of physical components shall be in accordance with Alabama NRCS Conservation Practice Standards, Irrigation Pipeline, Code 430, Irrigation Canal or Lateral, Code 320, Irrigation Field Ditch, Code 388, Structure for Water Control, Code 587, Pumping Plant, Code 533, and other pertinent conservation practice standards.

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

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

Water surface elevation. All systems for irrigation by surface methods shall be designed with water surface elevation at field takeout points adequate to provide required flow onto the field surface. A head of at least 4 inches shall be provided.

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

Irrigation Water Management. An Irrigation Water Management Plan meeting requirements of NRCS Conservation Practice Standard, Irrigation Water Management (449) shall be developed for use with this practice.

Aboveground, multi-outlet distribution pipeline.

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

For poly irrigation tubing, manufacturer's recommendations for maximum allowable working pressure shall be followed. If the manufacturer's recommendations are not available, the hoop stress formula in NRCS National Engineering Handbook (NEH) Part 636, Chapter 52, shall be used to determine maximum working pressure, using a Factor of Safety of 1.5.

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

Flow velocity. Velocity in the pipeline when operating at system capacity shall not exceed 7 feet per second unless appropriate surge protection is provided.

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

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

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

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

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

Materials. Pipe shall be aluminum or plastic material certified for above ground use. All fittings and couplers shall equal or exceed the pressure rating of the pipe with which they will be used. They shall be made of material which is recommended by the manufacturer for use with the pipe

Pipe and appurtenances shall be furnished with a coupling system which is compatible with the selected pipe material.

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

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

Corrosion protection shall be provided for aluminum pipe when:

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

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

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

Related structures. An open ditch supply shall include a permanent water control structure as the inlet to multi-outlet pipe.

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

Erosion control. The design of farm irrigation systems shall provide for the conveyance and distribution of irrigation water without causing damaging soil erosion. All unlined ditches shall have non-erosive gradients. If water is conveyed on slopes steep enough to cause excessive flow velocities, the irrigation system design shall provide for the installation of structural erosion control measures such as pipe drops, chutes, buried pipelines, and erosion-resistant ditch linings. Polyacrylamide may be applied for erosion control according to Alabama NRCS Conservation Practice Standard, Anionic Polyacrylamide (PAM) Application, Code 450 in lieu of, or in combination with structural measures.

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

Tailwater and excess runoff removal. Irrigation system designs shall include facilities of adequate capacity for safe removal of irrigation tailwater and storm water runoff. If erosion is a hazard, collection facilities (ditches) constructed for this purpose shall be on non-erosive gradients or stabilized by lining or structural measures. If field elevations do not permit non-erosive disposal of tailwater or excess water by gravity flow, the design shall provide for installation of pumping plants and other needed appurtenant structures. Ditches shall be protected from bank erosion.

If excess water will be reused for irrigation, the system shall include a tailwater reuse system that conforms to Alabama NRCS Conservation Practice Standard, Irrigation System, Tailwater Recovery, Code 447.

Additional Criteria Applicable to Subsurface Irrigation Systems

Subsurface irrigation systems shall be designed to maintain the water table at predetermined design elevations below the ground surface at all points in the application area.

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

Design of physical components shall be in accordance with Alabama NRCS Conservation Practice Standards, Subsurface Drain, Code 606,

Structure for Water Control, Code 587, Pumping Plant, Code 533, and other pertinent conservation practice standards.

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

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

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

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

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

Irrigation Water Management. An Irrigation Water Management Plan meeting requirements of Alabama NRCS Conservation Practice Standard, Irrigation Water Management, Code 449 shall be developed for use with this practice.

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

The installation and operation of an irrigation system for the purpose of chemical and/or nutrient application shall comply with all applicable federal, state and local laws, rules and regulations. This includes backflow and anti-siphon prevention measures to protect surface and ground water sources. Additionally, surface waters shall be protected from direct application and runoff.

Design of physical components shall be in accordance with Alabama NRCS Conservation Practice Standards Irrigation Pipeline, Code 430, Waste Transfer, Code 634, Structure for Water Control, Code 587, Pumping Plant, Code 533, and other pertinent conservation practice standards.

Capacity. The system shall have a design capacity adequate to supply the specified amount of chemical and/or nutrients to the design area in the specified operating period.

Nutrient and Pest Management. Chemicals, fertilizers, waste water, and liquid manure shall be applied in accordance with appropriate Alabama NRCS Conservation Practice Standards, Nutrient Management, Code 590; Pest Management, Code 595; and Waste Utilization, Code 633.

Additional Criteria Applicable to Reduce Energy Use

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

Reduction of energy use is calculated as average annual or seasonal energy reduction compared to previous operating conditions.

CONSIDERATIONS

When planning this practice the following items should be considered:

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

compaction. Designers should refer to soil survey information for the irrigated area during preliminary planning and conduct on-site soil investigations prior to final design.

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

- To improve surface irrigation efficiency surface tillage should be reduced when possible. The destruction of soil structure caused by physical and chemical disturbance can severely impede some soils ability to take in water.
- Impact of salt leaching requirements on system management, capacity, and drainage requirements.
- Effects of erosion and/or movement of sediment and sediment-attached substances carried by runoff including salinity, nutrients, pesticides, seeds and vegetative portions of invasive plants.
- Effect of elevated irrigation tailwater temperatures on downstream receiving waters.
- Irrigation system capacity should be determined based on appropriate design application efficiency. Design application efficiency should be no greater than 90 percent for properly designed level surface irrigation systems and a maximum of 80 percent for graded systems. Guidance for selecting design application efficiencies is provided in NRCS NEH Part 623, and NRCS NEH Part 652.
- Design, evaluation, and simulation models WINSRFR and SURFACE can be very useful tools in finalizing surface system designs.

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

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

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

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

PLANS AND SPECIFICATIONS

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

OPERATION AND MAINTENANCE

An operation and maintenance plan specific to the facilities installed shall be prepared for use by the landowner or operator responsible for operation and maintenance. The plan should provide specific instructions for operating and maintaining facilities to ensure they function properly. The plan shall include provisions to address the following:

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

Additionally for a subsurface irrigation, the plan shall include, as a minimum:

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

REFERENCES

USDA-NRCS, National Engineering Handbook, Part 623, Irrigation.

USDA-NRCS, National Engineering Handbook, Part 624, Drainage.

USDA-NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits.

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

USDA-NRCS, National Engineering Handbook, Part 652, National Irrigation Guide.

Alabama NRCS Conservation Practice Standards

Anionic Polyacrylamide (PAM) Application, Code 450
Integrated Pest Management, Code 595
Irrigation Canal or Lateral, Code 320
Irrigation Field Ditch, Code 388
Irrigation Pipeline, Code 430
Irrigation System, Microirrigation, Code 441
Irrigation System, Tailwater Recovery, Code 447
Irrigation Water Management, Code 449
Nutrient Management, Code 590
Pumping Plant, Code 533
Structure for Water Control, Code 587
Subsurface Drain, Code 606
Waste Transfer, Code 634
Waste Utilization, Code 633

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

IRRIGATION SYSTEM, TAILWATER RECOVERY

(No.)

CODE 447

DEFINITION

A planned irrigation system in which all facilities utilized for the collection, storage, and transportation of irrigation tailwater and/or rainfall runoff for reuse have been installed.

PURPOSE

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

- Conserve irrigation water supplies.
- Improve offsite water quality.
- Reduce energy use.

CONDITIONS WHERE PRACTICE APPLIES

Tailwater recovery systems are suitable for use on lands that are served by a properly designed and installed irrigation system where recoverable irrigation runoff and/or rainfall runoff flows can be anticipated under current or expected management practices.

This standard applies to the planning and functional design of irrigation tailwater recovery systems including, but not limited to, pickup ditches, sumps, collecting basins, pumping plants and pipelines. It does not apply to detailed design criteria or construction specifications for individual structures or components of the recovery system.

CRITERIA

General Criteria Applicable To All Purposes

The installation and operation of a tailwater recovery system shall comply with all federal, state and local laws, rules and regulations.

Appropriate NRCS standards and specifications shall be used in the design and construction of facilities needed for a tailwater recovery system. The criteria for the design of components not addressed in a NRCS Conservation Practice Standard shall be consistent with sound engineering principles.

Collection Facilities. Facilities for the collection of irrigation tailwater can be an integral part of irrigation systems covered by NRCS Conservation Practice Standards, Irrigation System, Surface and Subsurface (443), and Irrigation System, Sprinkler (442). These facilities may include, but are not limited to, ditches, culverts, pipelines, water control and/or grade stabilization structures or other erosion control measures, as needed.

Storage Facilities. Facilities are needed to store the collected water until it is redistributed in the irrigation system. Runoff volume and rate, as well as the required level of water control at the point where the tailwater is returned to the irrigation system, should be considered in determining the size of the storage facility.

For systems where tailwater is discharged into a collecting basin or regulating reservoir or into a pipeline having facilities for regulating fluctuating flows (i.e. a float valve), small sumps with frequently cycling pumping plants may be used. For systems unable to regulate flows, tailwater sumps or collection basins shall be made large enough to provide the regulation needed to permit efficient use of the water.

When energy sources for tailwater pump back systems are subject to interruption, safe emergency bypass areas cannot be provided, or tailwater discharges violate local or state regulations, tailwater storage requirements shall, as a minimum, include a volume adequate to store the complete runoff from a single irrigation set.

Sumps and collecting basins shall be equipped with inlets designed to protect the side slopes and the collection facilities from erosion. A

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your Natural Resources Conservation Service State Office or visit the Field Office Technical Guide.

dike, ditch, or water control structure shall be provided, if required by state law, to limit the entrance of rainfall runoff into the designed inlet. Sediment traps shall be installed as needed.

Conveyance Facilities. All tailwater recovery systems require facilities to convey water from the storage facility to a point of entry back into the irrigation system. These facilities may consist of a pumping plant and pipeline to return the water to the upper end of the field, or a gravity outlet having a ditch or pipeline to convey the water to a lower elevation in the irrigation system. Other components or combinations of components may be necessary as determined on a site-specific basis.

The capacity of conveyance facilities shall be determined by an analysis of the expected runoff rate, the planned irrigation collecting basin or regulating reservoir storage capacity, and the anticipated irrigation application. If the return flow is used as an independent irrigation supply rather than as a supplement to the primary irrigation water supply, the rate and volume of flow must be adequate for the method(s) of water application employed.

Additional Criteria Applicable To Improving Water Quality

Storage Facilities. Where additional storage is required to provide adequate retention time for the breakdown of chemicals in the runoff waters, storage facilities shall be sized accordingly. Allowable retention times shall be site specific to the particular chemical used.

Seepage from a storage facility shall be controlled to the extent possible when the storage facility is expected to receive chemical-laden waters. Control may be in the form of natural soil liners, soil additives, commercial liners, or other approved methods.

Where additional storage is required to provide for sediment deposition, storage facilities shall be sized accordingly. Allowable retention times shall be site specific to the particular soil type(s).

Additional Criteria Applicable to Reduce Energy Use

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

Reduction of energy use is calculated as average annual or seasonal energy reduction compared to previous operating conditions.

CONSIDERATIONS

Water Quantity

- Irrigation systems should be designed to limit tailwater volumes to that needed for effective operation. This reduces the need or minimizes the size and capacity of collection, storage, and transportation facilities.

  Where tailwater recovery systems are used to collect rainfall runoff for storage and use as an irrigation water source, the size and capacity of collection and storage facilities will be sized according to expected runoff volumes and rates as well as the expected crop water needs.

- Changes in irrigation water management activities may be necessary to optimize the use of return flows.

- Downstream flows or aquifer recharge volumes dependent on runoff will be reduced and could cause undesirable environmental, social, or economic effects.

Water Quality

- Effects on surface and groundwater quality by the movement of sediment and soluble and sediment-attached substances should be considered. Chemical-laden water can create a potential hazard to wildlife, especially waterfowl that are drawn to ponded water.

- Nutrient and pest management measures should be planned to limit chemical-laden tailwater as much as practical.

- Protection of system components from storm events and excessive sedimentation should be considered.

Other Considerations

- This practice may adversely affect cultural resources and must comply with NRCS General Manual 420, Part 401 during planning, installation, and maintenance.

- Effects on the visual quality of water resources should be also considered.

PLANS AND SPECIFICATIONS

Plans and specifications for irrigation tailwater recovery systems shall be prepared for specific field sites in accordance with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An Operation and Maintenance plan specific to the facilities installed shall be prepared for use by the landowner or operator responsible for operation and maintenance. The plan should provide specific instructions for operating and maintaining facilities to ensure they function properly. The plan shall include provisions to address the following, as a minimum:

- Periodic cleaning and re-grading of collection facilities to maintain proper flow lines and functionality.
- Periodic checks and removal of debris as necessary from trash racks and structures to assure proper operation.
- Periodic removal of sediment from traps and/or storage facilities to maintain design capacity and efficiency.
- Inspection or testing of all pipeline and pumping plant components and appurtenances, as applicable.
- Routine maintenance of all mechanical components in accordance with the manufacturer's recommendations.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE SPECIFICATION

IRRIGATION WATER MANAGEMENT

(Acre)

CODE 449

SCOPE

This practice shall consist of improving the application efficiency of irrigation water to the field(s) as shown on the conservation plan(s) or drawing(s).

IRRIGATOR SKILLS AND CAPABILITIES

The irrigator or decision maker shall possess the knowledge and capability to achieve the management objectives of this practice. Proper irrigation scheduling in both timing and amount, control of runoff, and uniform application of water across the field are primary concerns.

SYSTEM PERFORMANCE

Irrigation systems must be capable of applying water in a uniform manner and provide the irrigator with adequate control over water application. The uniformity shall be that which is economically achievable for a given irrigation method and area.

IMPLEMENTATION

The implementation of this practice should be by incremental application of recommended changes in the management system. The cooperator may not acquire all of the needed skills from a few technical assistance visits. Management changes in the system generally require a long-term relationship during which new methods can be demonstrated.

Follow-up visits should be made to provide further assistance and to verify the implementation of management improvements. The goal is to have an acceptable irrigation management system in place and an irrigator that applies efficient water management skills on a routine basis. Progress shall be reported to PRS following submission of irrigation records at the end of the first irrigation season.

RECORDKEEPING

The irrigator or decision-maker shall maintain records of irrigation that shall consist, at a minimum, of the dates of irrigation, volume or flow rate of water applied, duration of the irrigation, and basis for determining when irrigation was needed. Other records should be kept by the irrigator if they are deemed necessary or will be of assistance to the irrigator.

BASIS OF ACCEPTANCE

The practice shall be considered acceptable based on the following criteria:

A. General Criteria applicable to all Low-Intensity Irrigation Water Management (IWM)

- Complete the IWM Toolbox (CO449_JS_1)
- Complete the Colorado Modified Farm Irrigation Rating Index (FIRI) Jobsheet (CO449_JS_2)

- Complete the Nutrient Management Jobsheet (CO590_JS) if any nutrients are to be applied to the field.
- Review irrigation records and document copies in the case file
- Perform onsite inspection and determine principles of the practice have been adhered to

B. General Criteria applicable to all High-Intensity Irrigation Water Management

- Complete the IWM Toolbox (CO449_JS_1)
- Complete the Colorado Modified FIRI Jobsheet (CO449_JS_2)
- Complete the Nutrient Management Jobsheet (CO590_JS) if any nutrients are to be applied to the field
- Review records documenting evapotranspiration-based scheduling and document copies in the case file
- Review records documenting soil moisture and management allowable depletion (MAD) and document in the case file
- Review irrigation records with the producer and document copies in the case file
- Complete the graphing portion of the IWM Toolbox
- Perform onsite inspection to ensure the principles of IWM have been adhered to

C. Additional Criteria for Mountain Meadow Irrigation Systems

- Mountain meadow systems are defined as uncontrolled flood irrigation systems having a water bearing gravel or cobble substratum that is hydrologically connected to a stream channel.
- IWM is not required and shall not be applied to any mountain meadow irrigation system.
- Irrigation system improvements, with the exception of a Structure for Water Control (Code 587), that result in a controlled flood, sprinkler, or microirrigation system being applied on a mountain meadow field, removes the IWM exemption for the mountain meadow irrigation system.

D. Additional Criteria for the Arkansas River, Republican River, and Rio Grande River Watersheds

The Colorado Modified FIRI Jobsheet (CO449_JS_2) is not authorized for use in the Arkansas, Republican, or Rio Grande Watersheds. Instead, the Farm Irrigation Rating Index, Version 1.2 or higher, shall be completed for all irrigation water management practices in these watersheds.

E. Additional Criteria for the Ogallala Aquifer Initiative (OAI) Limited Root Zone Pilot and Drought Resilience Improvement Project (DRIP)

- High-Intensity Irrigation Water Management shall be applied including the use of continuous in-situ soil moisture monitoring
- The managed depth in the soil profile shall not exceed eighteen (18) inches in depth
- All tillage operations shall comply with the Residue and Tillage Management, No-Till/Strip Till/Direct Seed (Code 329) Standard
- Irrigation Systems shall comply with the Irrigation System, Microirrigation (Code 441) or Irrigation System, Sprinkler (Code 442) standards. Irrigation systems shall be designed to operate or be capable of being upgraded to operate under full automation, including water delivery, using data from installed soil moisture monitors

OPERATION AND MAINTENANCE

The owner/user should participate in the development of the items listed in the Operation and Maintenance plan prepared and provided for guidance in managing the operations for this practice.