EVALUATING A CENTRE PIVOT IRRIGATION SYSTEM

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Title: Workshop manual template

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Disclaimer
The information contained in this publication is based on knowledge and understanding at the time of writing (January 2010). However, because of advances in knowledge, users are reminded of the need to ensure that information on which they rely is up to date and to check the currency of the information with the appropriate officer of Industry & Investment NSW or the user’s independent advisor.

Contents

Equipment needed

To measure sprinkler coverage:

- Catchcans
- Weights to prevent catchcans blowing away
- A shovel to smooth catchcan area, and where necessary for partially burying the cans
- A measuring cylinder or jug with graduations in millilitres
- A 30-metre measuring tape; and possibly a short ruler
- Pegs or markers
- A calculator, a pen and evaluation sheets (you may need extra copies of the data sheets)
- Manufacturer's sprinkler performance charts

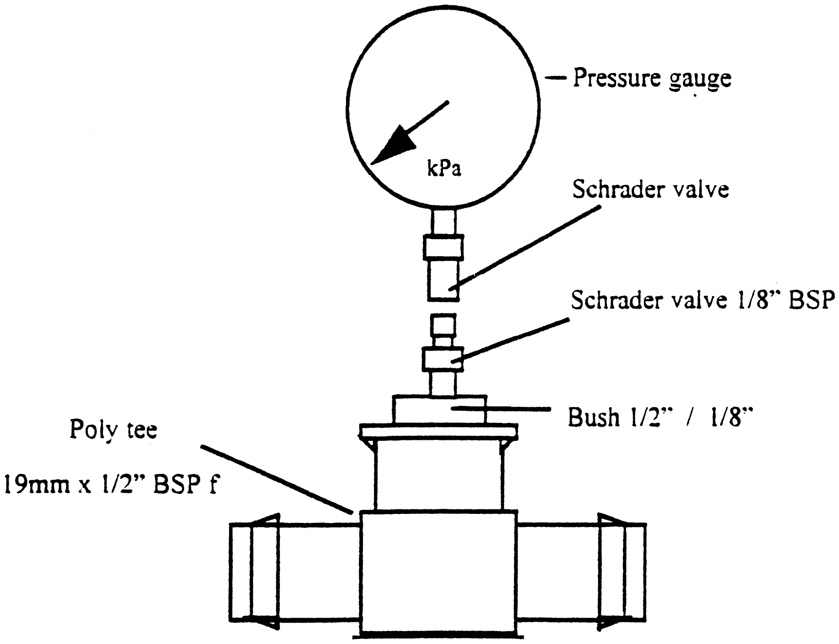
To measure flow:

- A container of known volume eg. 10 L bucket
- Stop watch

To measure pressure:

- An accurate pressure gauge with an appropriate scale so it works mid-range at normal pressures (say 0 to 400 kPa) to 1000 kPa
- Tees and fittings to install above pressure regulators (eg. Figure 1), sufficient for several emitters

Figure 1: Fittings and Schrader Valve



Evaluation method

To assess the performance of centre pivot irrigation system, it is necessary to measure the pressure at various points in the system, its operating speed and the output of the emitters using catchcans. To do this, work though the following procedure.

1. Record wind speed and direction (see Table 1). Field tests are ideally done in zero wind conditions and should not be done if the wind is stronger than a light breeze.
2. Fill out the first sections of the centre pivot data sheet with details about the crop, soils and the centre pivot. Measure the length of each span and the distance from the centre to the outer wheel track (where the travel speed will be measured).

Water output measurement

1. Choose a suitable location for the test so that catchcans may be placed across the pathway of the centre pivot. If possible, the location should be flat and level, and far enough ahead of the boom so that no water enters the catchcans before they are all set up. (For long pivots, the catchcans under the first one or two spans need not be recorded, as the time to pass over them is too great. There will be little effect on the calculations. However, the catchcan positions under these spans ***must*** be noted and the catch volume recorded as an ‘X’.)
2. Ideally, two rows of catch cans, with rows no more than 50m apart at the outside tower, should be used to check variation along the direction of travel.
3. Set out the catchcans no more than 5 metres apart. (For greater accuracy, use International Standard ISO 11545 maximum 3m apart.)
4. Ensure that the cans are in a straight line and that none will be displaced as the irrigator moves past.
5. Add at least two extra containers at the end to allow for changes in wind speed or direction.
6. If rain is likely, place another can away from the boom to record rain during the test. Any rain must be deducted from the amount caught in **each** catchcan.
7. When the irrigator has completely passed over all of the catchcans, measure and record the volumes in **each** container. Each volume MUST be written in the correct space on the field record sheet. If there is no catch can or no reading at a position, record it as an ‘X’.
8. Measure and record the tyre sizes and pressures.
9. Measure and record the width (or diameter) of the wetting pattern near the end drive unit. Placing a peg or marker at the limits of throw, then measuring the distance between after the machine has passed is the simplest way.

Speed measurement

Note that the pivot must be moving (at its normal speed) throughout the test, otherwise the difference in flow rates between the inboard and outboard sprinklers will give incorrect results.

1. Record the control panel settings/readings.

2. Measure the pivot's speed by staking out a measured distance (say 10 m) around the **outer** wheel track and recording the time required for the end drive unit to travel between the stakes.

Measuring pressure and flow

1. Attach tees and fittings (figure 1) above the pressure regulator and emitter at selected emitters for measuring the pressure. Select several, at least one on the first span, one on the last span and one in between, or you can measure a known emitter from each span, say the 3rd last emitter of each span.
2. Record the make, model, nozzle size or colour of each emitter tested, and its span and position number.
3. When the system is operating, record the pressure of the selected emitters using the pressure gauge. Take a reading at the centre too.
4. When the system is operating, measure the flow rate by holding the large container of known volume under one emitter and timing how long it takes to fill. Record measurements from at least one emitter per span and note the span and emitter position numbers. If a flow meter is fitted, take a reading at the centre too.

Calculating the results

1. After taking all measurements, complete the calculations. As the calculations for a centre pivot are quite complex, it is best to put the figures into a computer spreadsheet and let the computer work out the results. These may be available from your irrigation advisor or agency. For those who prefer to avoid the use of the computer, the full procedure is detailed in these notes.
2. Rank the volumes starting with the lowest amount, (1st, 2nd 3rd, and so forth). Do this for about one third of the cans.
3. Calculate the “weighted catch” by multiplying the volume collected in the catchcan by the position number of that catchcan. Follow the steps in your field record sheet.
4. Calculate the Average Application Depth per pass of your system using the Average Application Depth Table. Record the results in the Application Results table.
5. Calculate the Distribution Uniformity (DU) of your system using the DU Table. Record the results in the Application Results table.

Table 1: Wind Speed

Wind speed guide		
Visible effect	**Wind description**	**Speed (knots)**
Calm. Smoke rises vertically.	Calm.	00
Direction of wind shown by smoke drift but not wind vane.	Light air.	02
Wind felt on face. Leaves rustle. Vane moved by wind.	Light breeze.	05
Leaves and small twigs in constant motion. Wind extends light flag.	Gentle breeze.	09
Raises dust and loose paper. Small branches are moved.	Moderate breeze.	13
Small trees in leaf begin to sway. Crested wavelets on inland waters.	Fresh breeze.	18
Large branches in motion. Whistling heard in telegraph wires.	Strong breeze.	24
Whole trees in motion. Inconvenience felt when walking against wind.	Moderate gale.	30
Breaks twigs off trees. Generally impedes progress.	Fresh gale.	37
Slight structural damage occurs.	Strong gale.	44
Trees uprooted. Considerable structural damage. Seldom experienced inland.	Whole gale.	52
Very rarely experienced. Accompanied by widespread damage.	Storm. Hurricane.	60 68

Source: Bureau of Meteorology

Centre pivot data sheet – example

Property name: Roundabout **Date of field test:** 16/8/00

Crop	Lucerne
Location/block	Paddock 2 block 3
Soil texture of Block	Sandy loam over sand
Effective root depth	1.0 **metres**
Rootzone RAW	48 **mm**
Max. infiltration rate	60 **mm/h**
Irrigator make	Dizzy Lizzy
Designed Flow Rate	840 **USGPM** 53.0 **L/s** 0.19 **ML/hr**
Designed pressure (at centre)	25 **psi** 175 **kPa**
Number of Spans	6
Total length of spans (pivot radius to outer tower)	324 **metres**
Emitter make	Nelson
Emitter model	R3000 Rotators
Number of emitters along span	20
Length of overhang	25 **metres**
Wetted width (diameter) – end span	8 **m**
Number of emitters on overhang	8 sprinklers
End gun present	**Yes** [✓ **No**]
End gun radius	0
Pressure regulated?	**Yes** [✓ **No**]
Wind direction and speed during test	Light Breeze from north west
Catchcan Diameter	113 **mm**
Catchcan spacing	6 **metres**
Speed setting and depth applied – control panel	
Time to travel test distance	12 **minutes** 9 **seconds**
Distance travelled	10 **metres**

Centre pivot data sheet

Property name: **Date of field test:**

Crop	
Location/block	
Soil texture of Block	
Effective root depth	**metres**
Rootzone RAW	**mm**
Max. infiltration rate	**mm/h**
Irrigator make	
Designed Flow Rate	**USGPM L/s ML/hr**
Designed pressure (at centre)	**psi kPa**
Number of Spans	
Total length of spans (pivot radius to outer tower)	**metres**
Emitter make	
Emitter model	
Number of emitters along span	
Length of overhang	**metres**
Wetted width (diameter) – end span	**metres**
Number of emitters on overhang	
End gun present	**Yes No**
End gun radius	**metres**
Pressure regulated?	**Yes No**
Wind direction and speed during test	
Catchcan Diameter	**mm**
Catchcan spacing	**metres**
Speed setting and depth applied – control panel	
Time to travel test distance	**minutes seconds**
Distance travelled	**metres**

Irrigation System Calculations – example

Wetted area	**= π x (radius)^2 ÷ 10,000** **≈ 3.14 x (pivot radius + length of overhang + end gun radius)^2 ÷ 10,000** **≈ 3.14 x** (324 + 25 + 0)^2 **÷ 10,000** **≈ 3.14 x** (349)^2 **÷ 10,000** **≈ 3.14 x** 121,801 **÷ 10,000** **≈** 38.2 **ha**	**WA**
Distance Travelled	10 **metres**	**A**
Time for distance travelled	12 **minutes** 9 **seconds =** 729 **seconds**	**B**
Travel Speed = Distance travelled ÷ Test Duration (seconds) x 3600		
	= A ÷ B x 3600 = 10 ÷ 729 **x 3600** **=** 49.4 **metres per hour**	**C**
Pivot Radius (length to outer track)	324 **metres**	**R**
Circumference (outer wheel track) = 2 x π x pivot radius		
Circumference **2 x π ≈ 6.28**	**= 6.28 x R** **= 6.28 x** 324 **=** 2,035 **metres**	**E**
Time for one revolution = Circumference ÷ Travel speed		
	= **E ÷ C** = 2,035 ÷ 49.4 = 41.2 **hours**	**F**

Irrigation System Calculations

Wetted area	**= π x $(\text{radius})^2$ ÷ 10,000** **≈ 3.14 x $(\text{pivot radius + length of overhang + end gun radius})^2$ ÷ 10,000** **≈ 3.14 x (+ + $)^2$ ÷ 10,000** **≈ 3.14 x ÷ 10,000** **≈ ha**	**WA**
Distance Travelled	**metres**	**A**
Time for distance travelled	**minutes seconds**	**B**
Travel Speed = Distance travelled ÷ Test Duration (seconds) x 3600		
	= A ÷ B x 3600 **= ÷ x 3600** **= metres per hour**	**C**
Pivot Radius (length to outer track)	**metres**	**R**
Circumference (outer wheel track) = 2 x π x pivot radius		
Circumference **2 x π ≈ 6.28**	**= 6.28 x R** **= 6.28 x** **= metres**	**E**
Time for one revolution = Circumference ÷ Travel speed		
	= E ÷ C **= ÷** **= hours**	**F**

Checking System Capacity – example

System Capacity = Daily pump flow rate (L/day) ÷ Field irrigated area (m^2) or = Pump flow rate (ML/day) x 100 ÷ Field irrigated area (ha)		
Daily pump flow rate	= 53.0 L/s = 53.0 x 3600 secs x 24 hrs L/day = 4,579,200 L/day = 4.58 ML/day	
System Capacity	= L/day ÷ m^2 = 4,579,200 ÷ 382,000 = 12.0 mm/day Or = ML/day x 100 ÷ ha = 4.58 x 100 ÷ 38.2 = 12.0 mm/day	

Max daily crop water use = Max daily Point Potential ET x Crop Coefficient (Kc)		
Max daily PPETo	8.0 mm/day	**PPET**
Peak Kc (lucerne)	1.15	**Kc**
Max daily crop water use (CWU)	= PPET x Kc = 8.0 x 1.15 = 9.2 mm/day	**CWU**

Allowance must be made for:

- Pump Utilisation Ratio (P.U.R) – the proportion of the total possible time that pumping is actually occurring. This may be reduced for spraying, cultivating, machine and pump maintenance, dry movement of lateral move, refuelling, etc.
- Application Efficiency (Ea) – loss of water between the nozzle and root zone

This is the ***Managed*** System Capacity, and it should be at least equal to Max. daily CWU.

Pump Utilisation ratio:	0.80 (80%)	**PUR**
Application Efficiency:	0.90 (90%)	**Ea**
Managed System Capacity	= System Capacity x P.U.R x Ea = 12.0 x 0.80 x 0.90 = 8.6 mm/day	
Is Managed System Capacity adequate?	No	

Checking System Capacity

System Capacity = Daily pump flow rate (L/day) ÷ Field irrigated area (m^2) **or = Pump flow rate (ML/day) x 100 ÷ Field irrigated area (ha)**		
Daily pump flow rate	**= L/s** **= x 3600 secs x 24 hrs L/day** **= L/day** **= ML/day**	
System Capacity	**= L/day ÷ m^2** **= ÷** **= mm/day** **Or** **= ML/day x 100 ÷ ha** **= x 100 ÷** **= mm/day**	

Max daily crop water use = Max daily Point Potential ETo x Crop Coefficient (Kc)		
Max daily PPETo	**mm/day**	**ETo**
Peak Kc		**Kc**
Max daily crop water use (CWU)	**= ETo x Kc** **= x** **= mm/day**	**CWU**

Managed System Capacity (should be at least equal to max. daily CWU)

Pump Utilisation ratio:		**PUR**
Application Efficiency:		**Ea**
Managed System Capacity	**= System Capacity x P.U.R x Ea** **= x x** **=**	
Is Managed System Capacity adequate?		

Check tyre pressures – example

Tyre size:	16.9 x 24	
Tyre pressures – recommended	100 **kPa (**15 **psi)**	
Tyre pressures – measured	205 **kPa (**30 **psi)**	

Check tyre pressures

Tyre size:		
Tyre pressures – recommended	**kPa** **psi**	
Tyre pressures – measured	**kPa** **psi**	

Application results table – example

Nominal Average Application Depth (AAD) per pass: **= Specified flow rate (ML/hr) x Hours per rev ÷ WA (ha) x 100** **=** 0.19 **x** 41.2 **÷** 38.2 **x 100**	20.5mm
Measured Average Application Depth (AAD) per pass: From computer program OR own calculations using procedure at end of these notes.	19.5mm
The AAD should be compared to the rootzone RAW or the required deficit.	
Lower quarter output per pass: From computer program OR your calculations using procedure at end of these notes.	14.4mm
Distribution Uniformity: From computer program OR your calculations using procedure at end of these notes.	74 %

Distribution Uniformity of 90% is the benchmark (this is NOT the Irrigation Efficiency). Field conditions may make achieving this difficult.

Application results table

Nominal Average Application Depth (AAD) per pass: **= Specified flow rate (ML/hr) x Hours per rev ÷ WA (ha) x 100** **= x ÷ x 100**	**mm**
Measured Average Application Depth (AAD) per pass: From computer program OR own calculations using procedure at end of these notes.	**mm**
Lower quarter output per pass: From computer program OR your calculations using procedure at end of these notes.	**mm**
Distribution Uniformity: From computer program OR your calculations using procedure at end of these notes.	**%**
Coefficient of Uniformity$_H$: From computer program OR your calculations using procedure at end of these notes.	**%**

Field Record Sheet – example

If there is access to a computer program, only fill in columns A and B of this table. The computer will do the rest.

*For Centre Pivots, DU must be calculated using **weighted** catch can readings.* The following procedure uses weighted readings.

If you use a computer spreadsheet, ensure it uses weighted catch can readings.

Span #	Catchcan position number	Volume collected in can (mL)	Ranked volume	Weighted catch A x B
	A	**B**		**C**
1	1	X		
1	2	X		
1	3	X		
1	4	X		
1	5	X		
1	6	X		
1	7	X		
1	8	X		
1	9	X		
2	10	183		1830
2	11	221		2431
2	12	202		2424
2	13	209		2717
2	14	175	11	2450
2	15	206		3090
2	16	183		2928
2	17	177		3009
2	18	168	10	3024
3	19	143	6	2717
3	20	197		3940
3	21	177		3717
3	22	237		5214
3	23	197		4531
3	24	211		5064
3	25	189		4725
3	26	206		5356
3	27	191		5157

4	28	157	7	4396
4	29	210		6090
4	30	238		7140
4	31	250		7750
4	32	330		10560
4	33	272		8976
4	34	167	8	5678
4	35	259		9065
4	36	244		8784
5	37	142	5	5254
5	38	184		6992
5	39	208		8112
5	40	230		9200
5	41	224		9184
5	42	227		9534
5	43	212		9116
5	44	176		7744
5	45	189		8505
6	46	136	4	6256
6	47	168	9	7896
6	48	191		9168
6	49	194		9506
6	50	175	12	8750
6	51	224		11424
6	52	221		11492
6	53	187		9911
6	54	227		12258
O’hang	55	115	1	6325
O’hang	56	187		10472
O’hang	57	136	3	7752
O’hang	58	133	2	7714
	59			
	60			
	61			
Totals: TN = 1,666			**TC =**	**325,328**

Field Record Sheet

If there is access to a computer program, only fill in columns A and B of this table. The computer will do the rest.

*For Centre Pivots, DU must be calculated using **weighted** catch can readings.* The following procedure uses weighted readings.

If you use a computer spreadsheet, ensure it uses weighted catch can readings.

Span #	Catchcan position number	Volume collected in can (mL)	Ranked volume	Weighted catch A x B
	A	B		C

Totals:	**TN =**		**TC =**	

Conversion from Volume into depth

In order to convert Volume into depth (millimetres) a conversion factor is needed. The conversion factors are listed in the table on this page. Select the conversion factor by measuring the diameter of the mouth of the catchcan

For instance, if the diameter of the catchcan is 110 mm then the conversion factor from Table 2 will be 9.5 (circled).

If the cans collected 674 mL, then the conversion is the volume divided by the conversion factor;

674 mL ÷ 9.5 = 71 mm

Therefore the depth of water applied was 71 mm.

For catch-cans of 110 to 115 mm diameter across the top, dividing the collected amount by 10 to get mm of irrigation is likely to be accurate enough. For instance if you collected 674 mL, this approximates closely to a depth of 67.4 mm.

Table 2: Converting L to mm

Diameter of catchcan (mm)	Figure to divide the collected amount by
75	4.4
80	5.0
90	6.4
100	7.9
102	8.2
104	8.5
106	8.8
108	9.2
110	9.5
112	9.9
113	10.0
114	10.2
115	10.4
120	11.3
125	12.25
145	16.5
165	21.3
200	31.4
220	38.0

If you use 4 litre square plastic ‘ice cream’ containers, 1 litre collected in one of these is equivalent to 25 mm of irrigation. On a calculator, use

“water collected in mL” ÷ 40 = ……… mm

Calculating Average Application Depth and Application Rate – example

Average Application = Total of weighted catch cans ÷ Total of catch can numbers ÷ Conversion factor		
Total of catchcan numbers Add up the numbers in Column A where water was collected in the can. Ignore empty can numbers.	1,666	**TN**
Total of weighted catches Add up the numbers in Column C.	325,328	**TC**
Conversion Factor (Table 2) Our catchcans were 113 mm diameter	10.0	**CF**
Average Application Depth (AAD) per pass	**= TC ÷ TN ÷ CF** = 325,328 ÷ 1,666 ÷ 10.0 = 19.5 **mm**	**AAD**
Wetted width – end span	8 metres	**WW**
Average Application Rate (AAR) = emitter flow (L/h) ÷ (wetted width x emitter spacing)		
Emitter spacing	………2.7………… **metres**	**ES**
Emitter flow for Span: 6 Emitter no.: 120	………0.83…………… L/s	**EF**
AAR	**= (EF x 3600) ÷ (WW x ES)** = (0.83 x 3600) ÷ (8 x 2.7) = 2988 **L/h** ÷ 21.6 = 138 **mm/h**	**AAR**

Transfer the AAD figure to the Application Results Table (earlier).

AAR should be compared to the infiltration rate of the soil. If the AAR at the outer end of centre pivot is much greater than the infiltration rate, runoff will occur. Methods of reducing this problem should be investigated eg. installing outlets with a larger wetted diameter, increasing soil organic matter, using soil conditioners, etc.

Calculating Average Application Depth and Average Application Rate

Average Application = Total of weighted catch cans ÷ Total of catch can numbers ÷ Conversion factor		
Total of catchcan numbers Add up the numbers in Column A where water was collected in the can. Ignore empty can numbers.		**TN**
Total of weighted catches Add up the numbers in Column C.		**TC**
Conversion Factor (Table 2) Our catchcans were 113 mm diameter		**CF**
Average Application Depth (AAD) per pass	**= TC ÷ TN ÷ CF** **= ÷ ÷** **= mm**	**AAD**
Wetted width		**WW**
Average Application Rate (AAR) = emitter flow (L/h) ÷ (wetted width x emitter spacing)		
Emitter spacing	.... **metres**	**ES**
Emitter flow for Span: ___ Emitter no.: _____	.... **L/s**	**EF**
AAR	**= (EF x 3600) ÷ (WW x ES)** **= (x 3600) ÷ (x)** **= L/h ÷** **= mm/h**	**AAR**

Transfer the AAD figure to the Application Results Table (earlier).

AAR should be compared to the infiltration rate of the soil. If the AAR at the outer end of centre pivot is much greater than the infiltration rate, runoff will occur. Methods of reducing this problem should be investigated eg. installing outlets with a larger wetted diameter, increasing soil organic matter, using soil conditioners, etc.

Calculating the Distribution Uniformity (DU)

For Centre Pivots, DU must be calculated using weighted catch can readings. The following procedure uses weighted readings.

If you use a computer spreadsheet, ensure it uses weighted catch can readings.

Step 1 Determine the lowest quarter limit (LQ limit) where
LQ limit = Cumulative catchcan No. (TN) ÷ 4

Step 2 Determine the lowest quarter limit (LQ limit) where
LQ limit = Cumulative catchcan No. (TN) ÷ 4

Step 3 Continue to add the weighted catch until the total exceeds the figure for LQ limit. Use the figure before this, so the total is less than LQ limit.

Step 4 The figures you have added are your LQ catches – shade or highlight them on your Field Record Sheet.

Step 5 Follow the steps in the Distribution Uniformity Table

Step 6 Record your results in the Application Results Table

Lowest Quarter Catch Can Table – example

Rank	Catchcan position No.	Cumulative Catchcan No.	Weighted Catch C	Cumulative Weighted Catch
1	55	55	6325	6325
2	58	113	7714	14039
3	57	170	7752	21791
4	46	216	6256	28047
5	37	253	5254	33301
6	19	272	2717	36018
7	28	300	4396	40414
8	34	334	5678	46092
9	47	381	7896	53988
10	18	399	3024	57012
11	14	413	2450	59462
12	50	463	8750	68212
13				
14				

LQ LIMIT IS CUMULATIVE CATCHCAN NO = TN **÷ 4**

= 1,666 ÷ 4

= 416.5

413 is the closest to this, so the rank 11 catch, catch can no. 14, is the last LQ amount (highlighted above).

Therefore, the Low Quarter Weighted Catch is 59,462.

Lowest Quarter Catch Can Table

Rank	Catchcan position No.	Cumulative Catchcan No.	Weighted Catch C	Cumulative Weighted Catch
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

LQ LIMIT IS CUMULATIVE CATCHCAN NO = TN **÷ 4**

= **÷**

=

______ is the closest to this, so the rank ____ catch, catch can no. _____ is the last LQ amount (highlighted above).

Thus the Low Quarter Weighted Catch is ________________

Distribution Uniformity – example

Lowest quarter Limit	**= TN ÷ 4**	
	= 1,666 ÷ **4** = 416.5	**LQ Limit**
Lowest quarter Depth	**= Total Lowest quarter weighted volumes ÷ Total lowest quarter can positions**	**÷ conversion factor**
From the LQ Table, find the Cumulative Catchcan Number closest to LQ Limit.	= 413	**TNLQ**
From the LQ Table, find Cumulative Weighted Catch for TNLQ.	= 59,462	**TCLQ**
Lowest quarter depth	**= TCLQ ÷ TNLQ ÷ CF** = 59,462 ÷ 413 ÷ 10 = 14.4 mm	**LQ depth**
Distribution Uniformity	**= LQ Depth ÷ AAD x 100**	
	= 14.4 ÷ 19.5 **x 100** **=** 0.74 **x 100** **=** 74 **%**	**DU**
Transfer the DU figure to the Application Results Table (earlier).		

Distribution Uniformity

Lowest quarter Limit	**= TN ÷ 4**	
	= ÷ **4** =	**LQ Limit**
Lowest quarter Depth = Total Lowest quarter weighted volumes ÷ Total lowest quarter can positions ÷ conversion factor		
From the LQ Table, find the Cumulative Catchcan Number closest to LQ Limit.	=	**TNLQ**
From the LQ Table, find Cumulative Weighted Catch for TNLQ.	=	**TCLQ**
Lowest quarter depth	**= TCLQ ÷ TNLQ ÷ CF** = ÷ ÷ = mm	**LQ depth**
Distribution Uniformity	**= LQ Depth ÷ AAD x 100**	
	= ÷ x 100 **= x 100** **= %**	**DU**
Transfer the DU figure to the Application Results Table (earlier).		

Calculating Coefficient of Uniformity (CU_H) – example

Spreadsheet calculators for CU may be available from agencies, consultants, etc.

Coefficient of Uniformity is a measure of the deviation of each catch can depth from the average catch can depth. For Centre Pivots, the international standard is a modified method using weighted catch can readings, denoted as CU_H.

Span #	Catchcan position number	Catch can distance	Volume collected in can (mL)	Depth collected in can (mm)*	Weighted catch A x B
		A		B	C
centre	centre	0			
1	1	6	X	X	
1	2	12	X	X	
1	3	18	X	X	
1	4	24	X	X	
1	5	30	X	X	
1	6	36	X	X	
1	7	42	X	X	
1	8	48	X	X	
1	9	54	X	X	
2	10	60	183	18.3	1098
2	11	66	221	22.1	1459
2	12	72	202	20.2	1454
2	13	78	209	20.9	1630
2	14	84	175	17.5	1470
2	15	90	206	20.6	1854
2	16	96	183	18.3	1757
2	17	102	177	17.7	1805
2	18	108	168	16.8	1814
3	19	114	143	14.3	1630
3	20	120	197	19.7	2364
3	21	126	177	17.7	2230
3	22	132	237	23.7	3128
3	23	138	197	19.7	2719
3	24	144	211	21.1	3038
3	25	150	189	18.9	2835
3	26	156	206	20.6	3214
3	27	162	191	19.1	3094
4	28	168	157	15.7	2638

4	29	174	210	21	3654
4	30	180	238	23.8	4284
4	31	186	250	25	4650
4	32	192	330	33	6336
4	33	198	272	27.2	5386
4	34	204	167	16.7	3407
4	35	210	259	25.9	5439
4	36	216	244	24.4	5270
5	37	222	142	14.2	3152
5	38	228	184	18.4	4195
5	39	234	208	20.8	4867
5	40	240	230	23	5520
5	41	246	224	22.4	5510
5	42	252	227	22.7	5720
5	43	258	212	21.2	5470
5	44	264	176	17.6	4646
5	45	270	189	18.9	5103
6	46	276	136	13.6	3754
6	47	282	168	16.8	4738
6	48	288	191	19.1	5501
6	49	294	194	19.4	5704
6	50	300	175	17.5	5250
6	51	306	224	22.4	6854
6	52	312	221	22.1	6895
6	53	318	187	18.7	5947
6	54	324	227	22.7	7355
O’hang	55	330	115	11.5	3795
O’hang	56	336	187	18.7	6283
O’hang	57	342	136	13.6	4651
O’hang	58	348	133	13.3	4628
	59				
Total distances of cans with water: TD = 9,996			**Total of Weighted Catches: TWC = 195,197**		
Average Application Depth: AAD = TWC ÷ TD = 19.5 mm					

*** Convert mL to mm using conversion factor in Table 2**

Calculating Coefficient of Uniformity (CU_H)

Spreadsheet calculators for CU may be available from agencies, consultants, etc.

Coefficient of Uniformity is a measure of the deviation of each catch can depth from the average catch can depth. For Centre Pivots, the international standard is a modified method using weighted catch can readings, denoted as CU_H.

Span #	**Catchcan position number**	**Catch can distance**	**Volume collected in can (mL)**	**Depth collected in can (mm)***	**Weighted catch A x B**
		A		**B**	**C**
centre	centre	0			

Total distances of cans with water: TD =			**Total of Weighted Catches: TWC =**		
Average Application Depth: AAD = TWC ÷ TD = mm					

*** Convert mL to mm using conversion factor in Table 2**

Calculation sheet for Absolute Deviation – example

Catchcan position	Catchcan distance	Catchcan depth (mm)	Avaerage application on depth (AAD)	Absolute deviation (B-C)	Weighted absolute deviation (A X D)
	A	B	C	D	
Centre	0	-			
1	6	X			
2	12	X			
3	18	X			
4	24	X			
5	30	X			
6	36	X			
7	42	X			
8	48	X			
9	54	X			
10	60	18.3	19.5	1.2	72
11	66	22.1	19.5	2.6	171.6
12	72	20.2	19.5	0.7	50.4
13	78	20.9	19.5	1.4	109.2
14	84	17.5	19.5	2	168
15	90	20.6	19.5	1.1	99
16	96	18.3	19.5	1.2	115.2
17	102	17.7	19.5	1.8	183.6
18	108	16.8	19.5	2.7	291.6
19	114	14.3	19.5	5.2	592.8
20	120	19.7	19.5	0.2	24
21	126	17.7	19.5	1.8	226.8
22	132	23.7	19.5	4.2	554.4
23	138	19.7	19.5	0.2	27.6
24	144	21.1	19.5	1.6	230.4
25	150	18.9	19.5	0.6	90
26	156	20.6	19.5	1.1	171.6
27	162	19.1	19.5	0.4	64.8
28	168	15.7	19.5	3.8	638.4

29	174	21	19.5	1.5	261
30	180	23.8	19.5	4.3	774
31	186	25	19.5	5.5	1023
32	192	33	19.5	13.5	2592
33	198	27.2	19.5	7.7	1524.6
34	204	16.7	19.5	2.8	571.2
35	210	25.9	19.5	6.4	1344
36	216	24.4	19.5	4.9	1058.4
37	222	14.2	19.5	5.3	1176.6
38	228	18.4	19.5	1.1	250.8
39	234	20.8	19.5	1.3	304.2
40	240	23	19.5	3.5	840
41	246	22.4	19.5	2.9	713.4
42	252	22.7	19.5	3.2	806.4
43	258	21.2	19.5	1.7	438.6
44	264	17.6	19.5	1.9	501.6
45	270	18.9	19.5	0.6	162
46	276	13.6	19.5	5.9	1628.4
47	282	16.8	19.5	2.7	761.4
48	288	19.1	19.5	0.4	115.2
49	294	19.4	19.5	0.1	29.4
50	300	17.5	19.5	2	600
51	306	22.4	19.5	2.9	887.4
52	312	22.1	19.5	2.6	811.2
53	318	18.7	19.5	0.8	254.4
54	324	22.7	19.5	3.2	1036.8
55	330	11.5	19.5	8	2640
56	336	18.7	19.5	0.8	268.8
57	342	13.6	19.5	5.9	2017.8
58	348	13.3	19.5	6.2	2157.6
59					
	Total weighted absolute deviation TWAD				**31432**

Calculation sheet for Absolute Deviation

Catchcan position	**Catchcan distance**	**Catchcan depth (mm)**	**Average application on depth (AAD)**	**Absolute deviation (B-C)**	**Weighted absolute deviation (A X D)**
	A	**B**	**C**	**D**	
Centre					

	Total weighted absolute deviation TWAD				

Calculating Weighted Mean Absolute Deviation and CU_H – example

Mean Absolute Deviation	**= TWAD ÷ TWC** **=** 31,432 **÷** 195,197 **=** 0.161	**MAD**
Coefficient of Uniformity$_H$ = (1 – Mean Absolute Deviation) x 100		
CU_H	**= (1 – MAD) x 100** **= (1 –** 0.161**) x 100** **=** 0.839 **x 100** **=** 83.9 **%**	**CU_H**

Calculating Mean Absolute Deviation and CU_H:

Mean Absolute Deviation	**= TWAD ÷ TWC** **= ÷** **=**	**MAD**
Coefficient of Uniformity$_H$ = (1 – Mean Absolute Deviation) x 100		
CU_H	**= (1 – MAD) x 100** **= (1 –) x 100** **= x 100** **= %**	**CU_H**

Transfer the CU_H figure to the Application Results Table (earlier).

DU and CU conventional benchmark, no-wind:	**90%**

If the DU or CU is ***below*** an acceptable benchmark, then changes to the irrigation system may be required in order to improve it.

Relationship between DU and water depth variation ('Chemigation and Fertigation Basics for California' 2003, CalPoly):

DU	***Ratio of max depth to min depth***
70%	*2.2*
75%	*1.9*
80%	*1.7*
85%	*1.5*
90%	*1.3*
95%	*1.1*

2.2 means the highest watered area receives 2.2 times or 120% more than the lowest
1.1 means the highest watered area receives 1.1 times or 10% more than the lowest

How long to irrigate

Using the AAD value and the RAW value for the crop on this soil, it is possible to estimate how long to irrigate to ensure adequate wetting from this system. The DU also should be taken into account.

Example

AAD required compensating for DU	**= AAD ÷ DU** = 19.5 ÷ 0.74 = 26 mm	**G**
RAW for this crop from centre pivot data sheet	= 48 mm	**RAW**
Percentage of RAW applied per pass	**= AAD ÷ RAW x 100** = 19.5 ÷ 48 **x 100** = 41% (0.41)	**H**
Travel speed required to apply the full RAW and allow for DU on each pass	**= C x H x DU** = 49.4 x 0.41 x 0.74 = 15.0 **m/hr**	**K**
Time for one revolution at this speed	**= Circumference ÷ Travel speed** = E ÷ K = 2,035 ÷ 15.0 = 136 hours or 5.6 days	

How long to irrigate

Using the AAD value and the RAW value for the crop on this soil, it is possible to estimate how long to irrigate to ensure adequate wetting from this system. The DU also should be taken into account.

AAD required compensating for DU	**= AAD ÷ DU** = ÷ = mm	**G**
RAW for this crop from centre pivot data sheet	= mm	**RAW**
Percentage of RAW applied per pass	**= AAD ÷ RAW x 100** = ÷ **x 100** = % ( )	**H**
Travel speed required to apply the full RAW and allow for DU on each pass	**= C x H x DU** = x x = **m/hr**	**K**
Time for one revolution at this speed	**= Circumference ÷ Travel speed** = ÷ K = ÷ = hours or days	

Flow Record Sheet – example

Volume of large container: 10L Lc

	Nozzle type	Time for 10L (Seconds)	Flow measured Lc ÷ B (L/s)	Flow as per system design (L/s)	Flow difference C – D	Flow variation E ÷ D x 100 (± %)
	A	B	C	D	E	F
Span 1, last sprinkler	#15 15/128	71.4	0.14	0.13	+0.01	+7.7%
Span 2, last sprinkler	#22 11/64	37.6	0.26	0.25	+0.01	+4%
Span 3, last sprinkler	#29 29/128	23.8	0.42	0.40	+0.02	+5%
Span 4, last sprinkler	#34 17/64	18.75	0.53	0.52	+0.01	+4%
Span 5, last sprinkler	#40 5/16	14.29	0.70	0.67	+0.03	+4.5%
Span 6, last sprinkler	#44 11/32	12.09	0.83	0.76	+0.07	+9.2%

A variation of more than ± 5% may be unacceptable

Flow Record Sheet

Volume of large container: _______________ Lc

	Nozzle type	Time for …….. Lc (Seconds)	Flow – measured Lc ÷ B (L/s)	Flow – as per system design (L/s)	Flow difference C – D	Flow variation E ÷ D x 100 (± %)
	A	B	C	D	E	F
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
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Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						
Span: sprinkler:						

A variation of more than ± 5% may be unacceptable

Pressure Record Sheet – example

	Pressure measured above regulator (kPa)	Pressure specified above regulator (kPa)	Pressure difference A – B	Pressure Variation C ÷ B x 100 (%)
	A	**B**	**C**	**D**
Specified regulator pressure:				
At Pivot centre	200 kPa	175 kPa	+25 kPa	+14.3 %
Span 1, last sprinkler	177 kPa	155 kPa	+22 kPa	+14.2 %
Span 2, last sprinkler	152 kPa	137 kPa	+15 kPa	+10.9 %
Span 3, last sprinkler	141 kPa	123 kPa	+18 kPa	+14.6 %
Span 4, last sprinkler	138 kPa	112 kPa	+26 kPa	+23.2 %
Span 5, last sprinkler	115 kPa	107 kPa	+8 kPa	+7.5 %
Span 6, last sprinkler	102 kPa	105 kPa	-3 kPa	-2.9 %

Note that for pressure regulators to work properly, the pressure above a regulator should be at least 35 kPa (5 psi) higher than the specified regulator pressure.

Pressure Record Sheet

	Pressure measured above regulator (kPa)	Pressure specified above regulator (kPa)	Pressure difference A – B	Pressure Variation C ÷ B x 100 (%)
	A	B	C	D
Specified regulator pressure:				
At pivot centre:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				
Span: sprinkler:				

Note that for pressure regulators to work properly, the pressure above a regulator should be at least 35 kPa (5 psi) higher than the specified regulator pressure.