4.2 Field evaluation of solid set irrigation systems

Contents

4.2.1 System description

Solid set irrigation systems are characterised by permanently fixed sprinklers on rigid riser pipes, usually arranged in a grid pattern. The spacing between sprinklers varies considerably and the sprinkler layout pattern may be either square or triangular.

Long-lateral (bike-shift or long-line) systems are a special case. They are included in this section as evaluation procedures follow the same procedures as for solid set systems. Long-lateral systems typically have medium sized impact sprinklers mounted on a moveable stand, connected to permanently buried mainlines and hydrants by a long polythene pipe. Each sprinkler is moved manually around 6- 10 positions to cover 0.4 to 0.8 ha.

4.2.2 Special features for analysis

4.2.2.1 Wind effects

The performance of pressurised spray systems can be greatly affected by wind, particularly when nozzles are used on high angle settings or at high pressures that create smaller droplet sizes.

The uniformity testing should be carried out in conditions representative of those commonly experienced in the field. Wind speed and direction should be measured and recorded.

4.2.2.2 Permanent set system

Because solid set irrigation systems are not mobile any inherent non-uniformity (e.g. not the result of wind) is repeated each irrigation. There is an increased demand for high uniformity as there is no ‘smoothing’ effect as with moving systems, where inherent non-uniformities vary between events and tend to cancel.

4.2.2.3 Long lateral system

The long lateral irrigation systems are mobile, there is a ‘smoothing’ effect and non-uniformities may cancel each other with successive irrigation events. However, the uniformity achieved is very dependent on the placement of sprinklers at, and timing of, each shift.

4.2.2.4 Field variability

The performance of irrigation systems may vary at different positions in the field, mainly as a result of elevation changes.

A solid set system operating on a relatively flat, homogenous field should have similar performance in all positions. The assessor and client should discuss what testing is desired and the conditions under which any tests should be conducted.

4.2.3 Technical materials

4.2.3.1 Relevant standards

ISO 7749-2: 1990 *Agricultural irrigation equipment – Rotating sprinklers – Part 2: Uniformity of distribution and test methods*

ISO 8026 *Agricultural irrigation equipment – Sprayers – General requirements and test methods*

ISO 8026:1995/Amd.1:2000 *Agricultural irrigation equipment – Sprayers – General requirements and*

4.2.3.2 Technical references

Anon. 2001. *The New Zealand Irrigation Manual: A practical guide to profitable and sustainable irrigation.* Malvern Landcare/Environment Canterbury. Canterbury, New Zealand. (NZIM)

4.2.3.3 Abbreviations

Reference abbreviations used in text

Cal	Burt, Walker, Styles and Parrish. 2000
FDIS	ISO/FDIS 8224-1:2002
ISO	ISO 7749:2001
NZIM	Anon. 2001

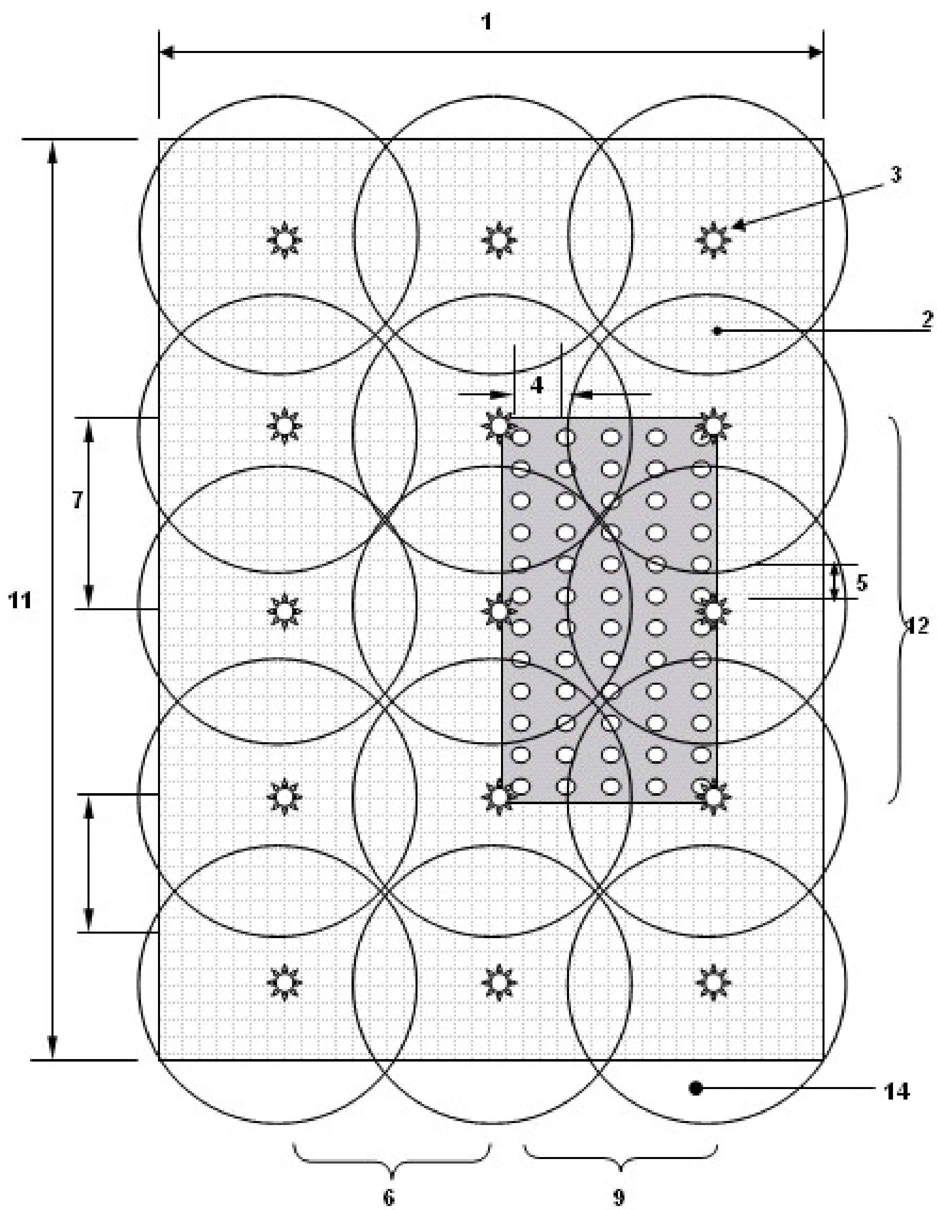
4.2.3.4 Related schedules and appendices

Section 2:	Conducting a field evaluation
Schedule 3	Seasonal irrigation efficiency assessment
4.2	Field evaluation of solid set irrigation systems
Appendix 5.2.2	Evaporation from collectors
5.4	Reporting format

4.2.4 Test procedures

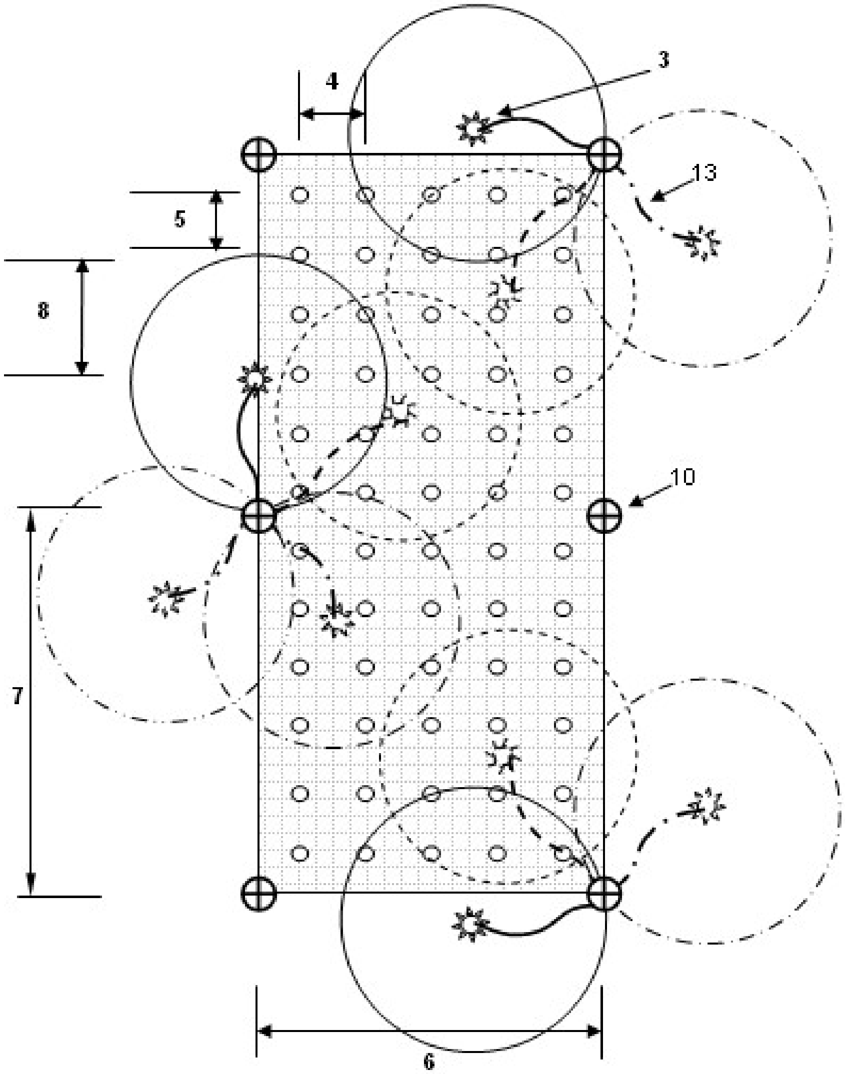
This schedule outlines procedures to be followed when assessing distribution uniformity of a solid set irrigation system as a ‘snapshot exercise’ under prevailing field conditions. To gain most benefit, conditions at the time of the test should be representative of those experienced in normal operation.

Because test conditions will vary, key conditions must be measured and recorded to assist any comparisons between subsequent tests of the system, or when benchmarking against other systems.



1	Irrigated area width *E*	7	Sprinkler column spacing D_{sc}
2	Irrigated area A_i	8	Sprinkler wetted radius, rw
3	Sprinkler	9	Extent of collector rows
4	Collector row (transverse) spacing, s_{cr}	11	Irrigated area length, L_t
5	Collector column spacing, s_{cc}	12	Extent of collector columns
6	Sprinkler row spacing D_{sr}	14	Area of potential off-target application

Fig.4.2.1: Field collector layout for solid-set systems



3	Sprinkler	8	Sprinkler wetted radius, r_w
4	Collector row spacing, s_{cr}	9	Extent of collector rows
5	Collector column spacing, s_{cc}	10	Hydrant
6	Hydrant row spacing	12	Extent of collector columns
7	Hydrant column spacing D_s	13	Long-lateral hose

Fig.4.2.2: Field collector layout for long-lateral systems showing only three hydrants and successive sprinkler positions

4.2.5 Test site

4.2.5.1 Location

If the irrigation site is level, the easiest location for the test is usually along an access track.

If the irrigation site is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

4.2.5.2 Site variability

If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several grid uniformity tests, or a combination of grid uniformity and pressure flow uniformity tests.

4.2.6 System survey

4.2.6.1 System layout

Prepare a map of the system recording the headworks, mainline, take-off points, sub-mains, manifolds and laterals.

Mark location of pressure regulators, flush valves and positions where tests are to be conducted (see example Fig. 4.1.1 , Fig.4.2.1).

4.2.6.2 Topography and elevation

If the field is not level, determine elevation differences between test sites and across the station as a whole.

Include a sketch of the profile along a typical sprinkler row with the results unless the ground surface is level.

4.2.7 System operation

4.2.7.1 Water quality

The water used for the test should be the same as that normally used for irrigation unmodified for the purpose of the test by any additional filtration, injection of chemicals or other processes unless specifically requested by the client (FDIS).

- For personal health and safety reasons, particular caution is necessary if water contains chemical treatments or biological wastes.

4.2.7.2 Sprinkler package – solid-set systems

If sprinkler design allows for different arrangements, use one setting that represents normal operation. The number of sprinklers or sprayers operating, and the horizontal and vertical settings of each, should remain constant during the test.

4.2.7.3 Sprinkler package – long-lateral systems

Testing long-lateral systems requires special consideration. A satisfactory sampling design includes assessing the distribution from each potential sprinkler position within the sampling area (Fig.4.2.2).

The number of sprinklers or sprayers operating, and the horizontal and vertical settings of each, should remain constant during the test.

4.2.7.4 Pressure

Standard tests should be run at the normal operating pressure, or as mutually agreed upon by client and tester. Ensure the pressure is maintained during the test (~ISO).

- To maintain constant pressure, ensure the system is not affected by other significant system draw-offs such as other irrigation machines or dairy sheds.

4.2.7.5 Test duration – Solid-set systems

The time duration selected for the test should be representative of that normally selected for irrigation and ensure sufficient volume is applied for reliable measurements to be obtained.

For solid set systems with long durations, a reduced time may be used.

- Record the test duration time and the normal operation irrigation set time. Ensure appropriate adjustments are factored into calculations.

4.2.7.6 Test duration – Solid-set systems

Long lateral systems require a modified operation plan under which selected sprinklers are moved at set intervals to imitate multi-event distribution patterns.

- Ensure each interval is of equal length, and long enough to provide sufficient applied depth for accurate measurements from collected volumes.
- Record the test duration time and the normal operation irrigation set time. Ensure appropriate adjustments are factored into calculations.

4.2.8 Environmental measurements

4.2.8.1 Wind

Record the direction and speed of the wind during the test period, and plot against relevant test locations on a map.

- Wind speed and direction relative to the system should be monitored at intervals of not more than 15 minutes and recorded (ISO).
- Wind conditions at the time of the test should be representative of those experienced in normal operation.
- Wind speeds greater than 3 m/s can have significant effects on uniformity (ISO).

At speeds greater than 3 m/s the tester and client must understand the limitations of the test results. The uniformity test should not be used as a valid measure of the sprinkler package if the wind velocity exceeds 3 m/s (ISO).

4.2.8.2 Evaporation

The uniformity test should be conducted during periods that minimise the effect of evaporation, such as at night or early morning or in winter months.

- Record the time of day, estimated or measured temperature and humidity when the test is conducted (ISO, Cal, IEP).
- Record the temperature and humidity in the test zone during the test period.

Determine evaporation rates using evaporation collectors identical to those used in uniformity testing.

- Place a control collector in a representative location upwind of the test area.
- Adjust readings for evaporation loss, following the procedures outlined in Appendix 5.2.2 Evaporation from collectors .

4.2.8.3 Topography

If the field is not level, conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package.

- Ensure sprinklers within the distribution test area are at the same pressure.
- Support the sprinkler distribution uniformity tests with sprinkler pressure flow adjusted testing.

4.2.9 Field observations

4.2.9.1 Crop type

Record the site's planting history for previous season and year.

Note crops planted in the area under examination, and stage of growth.

4.2.9.2 Crop appearance

Observe the crop for signs of stress or growth difference. Patchiness is indicative of poor system performance.

Measure or estimate the crop ground cover proportion.

4.2.9.3 Soil appearance

Dig, or auger, several holes within the irrigated area.

Assess the level of water penetration at each site and record. Note any soil features that indicate wetness, poor drainage or related properties and identify causes.

4.2.9.4 Soil properties

Determine the soil texture and depth of rooting.

Estimate or otherwise determine soil infiltration rate and soil water holding capacity.

4.2.9.5 Ponding

Assess the amount of ponding that occurs within the irrigated area while the system is operating. Note if water is ponding, running over the ground, or causing soil movement.

4.2.9.6 Runoff

Assess the amount of runoff from the irrigated area as a result of irrigation. Only consider volumes leaving the irrigated area and not recaptured for re-use.

High levels of run-off are uncommon under pressurised irrigation in New Zealand.

4.2.10 System checks

4.2.10.1 Filtration

Check filters and note nature and degree of contamination or blockage (Cal, IEP).

Identify when the filter was last checked or cleaned.

Identify if automatic cleaning or back-flushing is fitted and operational.

Check for presence of contaminants in lines: sand, bacteria/algae, precipitates etc

4.2.10.2 System leakages

Conduct an overall visual check (as possible) of headworks, mainline, hydrants, connection lines and the distribution system to identify any leakages or other losses from the system.

4.2.10.3 Sprinkler package

Before testing a system, verify that the sprinkler package has been installed according to the design specifications, unless specified otherwise by the client (ISO).

4.2.11 Flow measurement

4.2.11.1 Total system flow

Record the water flow rate as measured by a fitted water meter with the system operating as normal. Wait until flow rates stabilise (<15 minutes) before taking reading.

It may be necessary to take beginning and ending meter readings over a set time period to determine flow rate.

4.2.11.2 Energy use

Obtaining energy consumption data for the period covered by flow measurement enables calculation of irrigation energy costs.

4.2.12 System pressure

4.2.12.1 Mainline pressures

With system operating, measure:

- Pump discharge pressure
- Mainline pressure after filters and control valves

Optionally measure:

- Filter head loss
- Pump control valve head loss
- Throttled manual valve head loss

For multiple block solid-set systems, and long-lateral systems, measure pressure at each hydrant

4.2.13 Sprinkler performance

4.2.13.1 Wetted radius

Determine the wetted length and width of the irrigated area, extending to approximately 75% of the wetted radius of outer-most sprinklers.

4.2.13.2 Sprinkler pressure / flow

Measure the pressures and flows from 12 sprinklers chosen at random across the irrigated area. Ensure sprinklers chosen are of the same specifications.

- Capture all flow without flooding the nozzle or affecting pressure.
- Shroud the sprinkler with a loose hose and collect discharge in a container of at least 20 litres.
- Measure and record the time in seconds to fill the container. (Filling to the neck of a bottle or drum container will increase accuracy.

4.2.13.3 Grid uniformity test – solid-set systems

Arrange a grid of collectors between six adjacent sprinklers (three in each of two rows) in a representative part of the system (Fig.4.2.1). The grid must fit within the six sprinklers.

Define *collector columns* as the lines perpendicular to the sprinkler rows and *collector rows* as the lines parallel to the sprinkler rows.

4.2.13.4 Grid uniformity test – long-lateral systems

Arrange a grid of collectors between four or six adjacent hydrants in a representative part of the system (Fig.4.2.2). The grid must fit within the selected hydrants.

Define *collector columns* as the lines perpendicular to the hydrant rows and *collector rows* as the lines parallel to the hydrant rows.

4.2.13.5 Collector placement

The maximum spacing between collectors should be 3m for sprayers or 5.0 m for spinners, impact sprinklers or rotators (~ISO 11545).

Ensure the spacing between collector columns (S_{cc}) is a factor of the sprinkler row spacing (D_{sc}). E.g. If Ds = 10 m, S_{cc} = 2.0, 3.33, or 5.0 m

- Ensure the first and last columns of collectors are positioned one half column spacing from the first and last test sprinklers respectively.

Ensure the distance between collector rows (S_{cr}) is a factor of the sprinkler rows spacing (D_{sr})

- Ensure the first row of collectors is positioned one half sprinkler row spacing from the sprinklers.

Measure and record the position of each collector in the grid.

4.2.13.6 Operation – solid-set systems

The test should run for a complete irrigation set. However, in the interests of time efficiency, a shorter duration may be agreed in consultation with the system owner. The system must be shut off before collector readings begin.

4.2.13.7 Operation – long-lateral systems

The test must be repeated with sprinklers at each position that distributes water to any position within the test grid. It is unrealistic to run each sub-test for a complete irrigation set, but the duration must be sufficient to collect enough water for accurate measurement.

In low evaporation periods it may be possible to read collector volumes only at the end of the full test. The system must be shut off before final collector readings begin.

However if evaporation is significant the system must be shut off, and collectors read after each set, with appropriate evaporation adjustments made. Recorded depths for each collector will then be summed for uniformity analysis.

4.2.14 Optional tests

Additional tests may be undertaken for specific purposes as agreed with the owner.

4.2.15 Performance indicators

4.2.15.1 Distribution uniformity

Determination of field DU is a prime output from this evaluation. The approach taken is to determine a base value of distribution uniformity from sprinkler grid uniformity, and adjust the result to account for sprinkler flow variation and other contributing factors.

Where possible, the relative contribution made by each variable is estimated. This identifies those factors where system alterations may have most effect. Distribution uniformity is not strictly an efficiency measurement so is reported as a decimal value.

4.2.15.2 Uniformity coefficient

The statistical uniformity coefficient based on Christiansen's Uniformity Co-efficient is an alternative measure that can be reported Eqn 33 Christiansen coefficient). The uniformity co-efficient is not strictly an efficiency measurement so is reported as a decimal value.

4.2.15.3 Application depth

Application depth is calculated and compared to soil water holding capacity. This provides an indication of possible deep percolation, with subsequent impacts on irrigation efficiency, or potential moisture deficit with resultant reduced crop yield.

4.2.15.4 Application rate

Instantaneous application rates are calculated and compared to soil infiltration rates. This provides an indication of possible surface redistribution, with subsequent impacts on uniformity.

4.2.16 Distribution uniformity

4.2.16.1 Field DU_{lq}

Estimate an overall field distribution uniformity by combining contributing variable factors, (grid uniformity, sprinkler flow variation and ponding factor) using the Clemmens-Solomon statistical procedure, Eqn 27.

$$FDU_{lq} = \left[1 - \sqrt{(1 - GDU_{lq})^2 + (1 - QDU_{lq})^2 + (1 - F_{ponding})^2}\right]$$

Where:

FDU_{lq} is low quarter field distribution uniformity

GDU_{lq} is low quarter grid distribution uniformity

QDU_{lq} is low quarter flow distribution uniformity

$F_{ponding}$ is surface redistribution from ponding

4.2.16.2 Grid distribution uniformity, GDU_{lq}

Calculate low quarter grid distribution uniformity, GDU_{lq}, using Eqn 29 after adjusting application depths for evaporation, as described in Appendix 5.2.2 Evaporation accounting.

4.2.16.3 Sprinkler flow uniformity, QDU_{lq}

Calculate low quarter flow distribution uniformity from measured sprinkler flows along the sprayline length 4.2.13.2 Sprinkler pressure / flow) using the low quarter uniformity formula, Eqn 29.

4.2.17 Uniformity coefficient

Optionally, calculate the statistical uniformity coefficient, CU, using the Christiansen formula, Eqn 33.

4.2.18 Application Depth

4.2.18.1 Required adjustments

To make valid assessments, the depths measured by collectors must be adjusted to account for evaporation losses. This reference application depth can be compared to a total system application depth.

4.2.18.2 Evaporation adjustment

Make adjustments for evaporation losses as set out in Appendix 5.2.2 Evaporation from collectors .

4.2.18.3 Overlap accounting

Overlap effects are measured by the sampling techniques applied in the field. No further account should be made in calculations.

4.2.18.4 Total system application depth

The application depth based on total system flow, cycle duration and irrigated area is calculated using Eqn 43 Mean system application depth. In the case of long-lateral systems, the irrigated area is the whole area divided by the number of sprinkler positions used per hydrant.

4.2.18.5 Irrigated area application depth – solid-set systems

Calculate the mean application depth for the irrigated area as the average of the grid depths collected adjusted for evaporation losses.

Determine the overall minimum and maximum application depths.

4.2.18.6 Irrigated area application depth – long-lateral systems

Determine the mean applied depth for long lateral systems using Eqn 44 based on the average flow and the average wetted area per sprinkler as for drip-micro systems.

4.2.19 Application rates

Under a solid set system, the application rate is relatively constant. High instantaneous application rates can lead to ponding and surface redistribution.

4.2.19.1 Instantaneous application rate

Calculate the application rate (mm/h) for the grid, using those depths collected in the grid analysis, using Eqn 46.