4.3 Field evaluation of sprayline irrigation systems

Contents

4.3.1 System description

A sprayline irrigation system irrigates a field by sequentially moving a static line of sprinklers to predetermined parallel locations across a field. Water is discharged under pressure from the sprinklers which are set at even intervals along a lateral pipeline.

Irrigated strips overlap at the edges to ensure even coverage. The evenness of application across the irrigated strip, and the evenness of application along the length of the sprayline, both contribute to overall irrigation distribution uniformity.

Recognised categories include hand-move pipes, side-roll systems, and various towable spraylines.

a. Hand-move pipes
Hand-move pipes are typically aluminium lengths that clip together with quick couplings to fit field dimensions. A sprinkler is mounted on a riser at one end of each pipe section, so the sprinkler spacing is set.

Shifting is manual, with pipe sections separated, moved and rejoined at each position.

b. Side-roll systems
Side-roll systems consist of sprinklers mounted on aluminium or steel pipeline sections. Each section acts as the spindle of a centrally fitted wheel. Repeating units are joined to form the sprayline to fit field dimensions. The sprinklers are mounted on rotating couplings to ensure horizontal alignment regardless of spindle position. Sprinklers are mounted at pipeline height, and spacing is essentially set.

Shifting is done by rolling the complete line sideways to the next position in the irrigation sequence.

c. Towable spraylines
Towable spraylines consist of sprinklers fitted at set intervals on a polyethylene lateral. The sprayline length is generally set.

Shifting is done by towing the complete sprayline by one end to the next position in the field.

Sprayline systems make irrigation feasible in many areas where other techniques are not suitable. Some types are easily transported between fields even over relatively long distances, and can be used to irrigate irregularly shaped areas. They are readily removed from the field to allow cultivation and other practices to be carried out unhindered.

4.3.1.1 This Schedule

This schedule outlines procedures to be followed when assessing distribution uniformity of sprayline systems in the field. It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

4.3.2 Special features for analysis

4.3.2.1 Overlapping strips

The uniformity of water application for an entire field is likely to be increased through the overlapping of adjacent irrigation strips.

Field application uniformity can be estimated by virtual overlays of test data from a single irrigation strip. The sprayline is measured for one set position, and measurements from outer edges mapped on to the corresponding measurements on the opposite side.

4.3.2.2 Wind effects

The performance of pressurised spray systems such as spraylines can be greatly affected by wind, particularly when nozzles are used on high angle settings or at high pressures that create smaller droplet sizes. Strong cross winds are likely to have greatest effects.

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.

4.3.2.3 Field variability

The performance of a sprayline may vary at different positions in the field. Contributing factors include topographic variation and elevation changes and soil effects.

A sprayline 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.

4.3.2.4 Off-target application

Spraylines may be operated with sprinklers set at either end of the strip to ensure at least the target application depth is applied to the whole crop. A variable percentage of water will be applied off target so application efficiency is reduced, more so on short runs.

4.3.2.5 Alternate sets

Spraylines may be set in different positions during successive irrigation rotations. If set positions are moved one half of set-width, the overall uniformity will increase as non-uniformity is compensated for.

4.3.3 Technical materials

4.3.3.1 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 test methods* AMENDMENT 1

ISO/FDIS 8224-1:2002 *Traveller irrigation machines – Part 1: Operational characteristics and laboratory and field test methods (FDIS)*

ISO 8224/1 – 1985 *Traveller irrigation machines – Part 1: Laboratory and field test methods*

4.3.3.2 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)

4.3.3.3 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

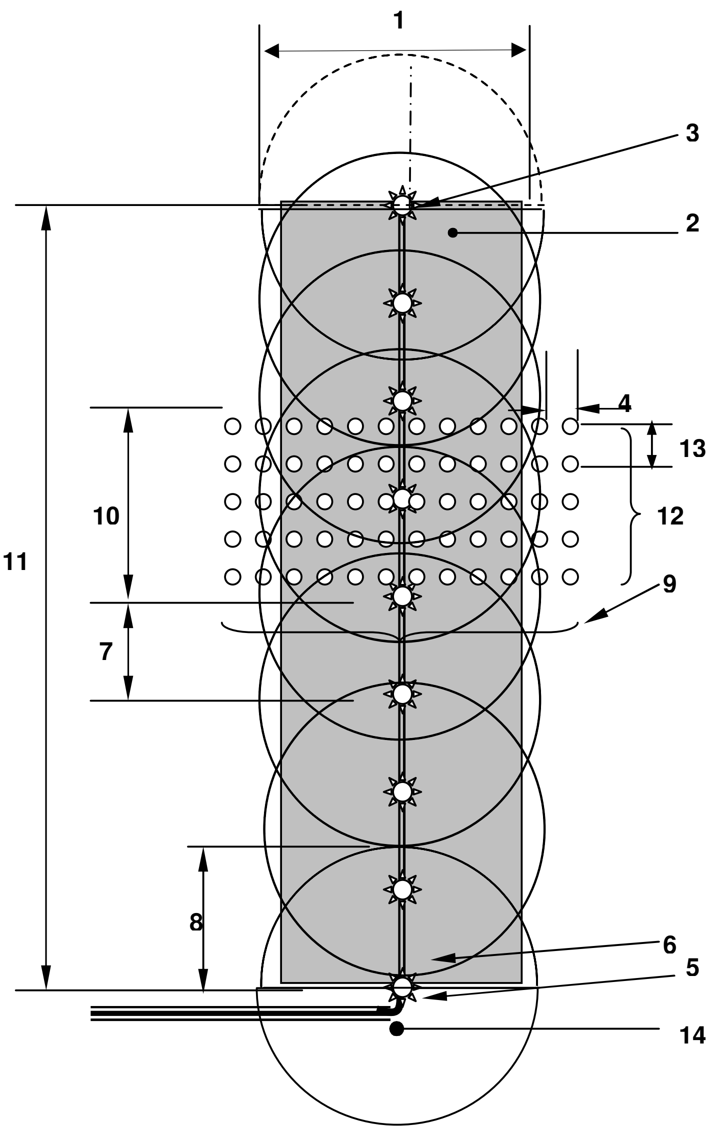
4.3.3.4 Related schedules and appendices

Section 2:	Conducting a field evaluation
Schedule 3	Seasonal irrigation efficiency assessment
Appendix 5.2.2	Evaporation from collectors
Appendix 5.2.3	Overlapping systems
Appendix 5.4	Reporting format

4.3.4 Test procedures

This schedule outlines procedures to be followed when assessing distribution uniformity of sprayline irrigation systems 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 same system, or when benchmarking against controlled test results or tests of other systems.



1	Irrigation strip width, lane width, *E*	8	sprinkler wetted radius, r_w
2	Irrigation strip accounting for overlap	9	extent of collector rows
3	Sprayline: final sprinkler	10	transverse line layout zone (= 2 D_s)
4	collector row (transverse) spacing, s_{cr}	11	length of strip, sprayline length, Lt
5	Hydrant or end of mainline	12	extent of collector columns
6	Sprayline: initial sprinkler	13	collector column (longitudinal) spacing, s_{cc}
7	sprinkler spacing D_s	14	area of potential off-target application

Fig 4.3.1: Field collector layout for sprayline systems

4.3.5 Test site

4.3.5.1 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.

4.3.5.2 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.

4.3.6 System survey

4.3.6.1 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 4.3.1).

4.3.6.2 Irrigation strip

Measure the irrigation strip length and width as defined in Fig 4.3.1.

4.3.6.3 Off-target application (F_{target})

Estimate the proportion of discharge that falls outside the target area (off the ends of the sprayline or sides of the field as a whole).

4.3.7 System operation

4.3.7.1 Sprinkler package

If the water distribution systems 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.

4.3.7.2 Test duration

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

If testing does not continue for the full length of a normal irrigation application, record the test duration time and the normal operation irrigation set time.

4.3.8 Environmental measurements

4.3.8.1 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 sprayline 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).

4.3.8.2 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 .

4.3.8.3 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.

4.3.9 Field observations

4.3.9.1 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.

4.3.9.2 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.

4.3.9.3 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.

4.3.9.4 Soil properties

Determine the soil texture and depth of rooting.

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

4.3.9.5 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.

4.3.9.6 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.

4.3.10 System checks

4.3.10.1 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

4.3.10.2 Sprinklers

Record the nozzle type and orifice(s) fitted

Check sprinklers are operating and set correctly (to horizontal)

Randomly select at least 12 sprinklers or sprayers along the length of the machine. Inspect them for blockages and record the cause of any blockages found. Assess orifice wear with a gauge tool or drill bit (IEP, Cal).

Check sprinkler height above canopy meets manufacturer's recommendations (Cal).

4.3.10.3 Sprayline leaks

Check for damage to spraylines or misfit connections. Assess scale of leakages if any.

4.3.11 Flow measurement

4.3.11.1 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.

4.3.11.2 Energy use

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

4.3.12 System pressure

4.3.12.1 Headworks 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

4.3.12.2 Mainline pressures

For moveable machines or systems, measure:

- Pressure at each hydrant

If hydrants are on a common mainline, measure pressures at each hydrant while the system is operating at furthest hydrant from the pump/filter.

4.3.12.3 Sprayline pressure

With the system operating, measure sprayline pressures:

- At the first available pressure test point or outlet downstream of the elbow or tee at the top of the inlet structure (ISO, IEP, Cal).
- At the last outlet(s) or end(s) of the pipeline (IEP, Cal). If an end-gun with booster pump is fitted, ensure the pressure reading is taken upstream of the pump.

If pressure is read at a sprinkler, use a pressure gauge with a pitot attachment (Fig 5.3.5 Measurement of sprinkler pressure). Depending on sprinkler design, this may require dismantling the units (IEP).

Lateral pressures cannot be inferred from readings at the sprinkler if pressure regulators are installed.

4.3.13 Sprinkler performance

4.3.13.1 Wetted radius

Determine the wetted width of the sprayline (sprinkler wetted radius) to the nearest 10cm in at least three locations.

4.3.13.2 Sprinkler pressure / flow

Measure the pressures and flows from 12 sprinklers chosen at random along the length of the sprayline. Ensure sprinklers chosen are of the same specifications.

- Capture all flow without flooding the nozzle or affecting pressure.
- Shroud the sprinkler or sprayer 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.

4.3.13.3 Grid uniformity test

Arrange a grid of collectors between three correctly functioning adjacent sprinklers along a representative part of the sprayline (Fig 4.3.1). The grid must extend beyond the sprinkler wetted radius on both sides of the sprayline.

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

4.3.13.4 Collector placement

Useful assessment of uniformity comes from multiple transverse assessments and consideration of overlap effects. In the case of a stationary system such as a sprayline, a grid of collectors should be established between adjacent sprinklers and extending beyond the full width of the wetting pattern.

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

Ensure the spacing between collector columns (S_{cc}) is a factor of the sprinkler spacing (*Ds*).

- 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 half the wetted strip width (*E*).

- E.g. If E = 20m, E/2 = 10m, S_{cr} = 2.0, 3.33 or 5.0 m.
- Ensure the first row of collectors is positioned one half column spacing from the first and last test sprinklers respectively.
- The lines of collectors must extend to the full wetted radius of the water distribution system, allowing for any skewing as a result of wind effects.

Measure and record the position of each collector relative to the sprayline.

4.3.13.5 Operation

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.

4.3.14 Optional tests

If desired, repeat tests may be run to determine distribution uniformity under different weather (wind) conditions, or with the sprayline in a different field location or locations.

On highly variable terrain, a sprinkler pressure flow test should be considered to establish performance variability across the entire system.

4.3.14.1 Pressure derived flows

As an alternative to using measured sprinkler flows, pressure derived flows may be calculated for each of the pressure measurements taken along the sprayline (see 4.3.13.2 Sprinkler pressure / flow) using the emitter pressure flow relationship (Eqn 22).

If the emitter discharge exponent and coefficient are not available from manufacturers' data they can be determined as described in Section 4.1.13.7 Adjusted pressure test using Eqn 24 and Eqn 23. For most sprinklers, the discharge exponent, x, is approximately 0.5 and this value may be substituted if alternative data is not available. The variability may be calculated without a specific discharge co-efficient without compromising validity.

4.3.15 Performance indicators

4.3.15.1 Distribution uniformity

A determination of field DU is a prime output from evaluations conducted using this Code of Practice. The approach taken is to determine a base value of distribution uniformity from a critical field test procedure, and adjust the result to account for 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.

4.3.15.2 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.

To make valid assessments of sprayline performance, the depths measured by collectors must be adjusted to account for evaporation losses and for the effect of overlaps from adjacent irrigation sets (strips). This reference application depth can be compared to a total system application depth.

4.3.15.3 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.

4.3.16 System uniformity

4.3.16.1 Required adjustments

The flow measurements used to assess uniformity are a non-random sample, and cover only part of an irrigation event. Determination of global 'field uniformity' requires that adjustments are made to account for various factors, including pressure variation, overlap and unequal system drainage.

Adjustments are also required to account for evaporative losses from collectors while field data collection is undertaken.

4.3.16.2 Field distribution uniformity, FDU_{lq}

Estimate overall field distribution uniformity (FDU_{lq}) by combining contributing variable factors using the Clemmens-Solomon statistical procedure, Eqn 27.

Overall uniformity incorporates the distribution pattern of the overlapped sprinklers, and the flow variation from individual sprinklers. In addition, it may be adjusted for unequal drainage after system shut-down.

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

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

$F_{drainage}$ is the uneven drainage factor

4.3.16.3 Grid distribution uniformity, GDU_{lq}

Calculate low quarter grid distribution uniformity, GDU_{lq}, after adjusting application depths for evaporation and overlap, as described in Appendix 5.2.2 Evaporation from collectors and Appendix 5.2.3 Overlapping systems

Calculate GDU_{lq} using Eqn 29.

4.3.16.4 Flow distribution uniformity, QDU_{lq}

Calculate low quarter flow distribution uniformity from measured sprinkler flows along the sprayline length (4.3.13.2 Sprinkler pressure / flow) using the low quarter uniformity formula, Eqn 29.

4.3.17 Other uniformity factors

4.3.17.1 Pressure distribution uniformity (PDU_{lq})

The pressure distribution uniformity coefficient describes a theoretical uniformity determined from pressure variation across the field, and the performance characteristics of the emitters.

If used in determining Field DU, PDU_{lq} replaces sprinkler flow uniformity, QDU_{lq}.

Pressure distribution uniformity (PDU_{lq}) is calculated from pressure derived flows, using the low quarter uniformity formula Eqn 29.

4.3.17.2 Pressure derived flows

Pressure derived flows are calculated for each of the pressure measurements taken across the field (see App 3.2: Pressure measurement) using the emitter pressure flow relationship, Eqn 22.

If the emitter discharge exponent and coefficient are not available from manufacturers' data they must be determined from pressure flow data collected in the field and calculated using Eqn 23 and Eqn 24.

4.3.17.3 Uniformity from alternate sets

Calculate a potential distribution uniformity assuming successive irrigation stagger set positions.

Determine alternate set uniformity by overlaying left side collector data on the right side data (See Appendix 5.2.3 Overlapping systems).

4.3.18 Application depth

4.3.18.1 Reference applied depth for strip

Calculate a reference applied depth (mm) for the strip using collector data adjusted for evaporation and overlapped as calculated in Eqn 46.

Calculate the minimum and maximum application depths after adjustments as above.

4.3.18.2 Total system application depth

Calculate application depth based on total system flow, cycle duration and irrigated area using Eqn 43. This assumes that each strip is overlapped from each side, so each strip receives the full volume of water applied during one irrigation set.

4.3.19 Application rates

4.3.19.1 Reference application rate

Calculate the application rate (mm/h) for the grid from the mean application depth and test duration assuming no overlap, using Eqn 46.

4.3.20 Pressure variation

4.3.20.1 Mainline pressures

Determine the mean, the maximum and minimum pressures at the hydrants if applicable.

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