4.6 Field evaluation of linear move irrigation machines

4.6.1 System description

A linear move irrigation machine consists of a lateral pipeline supported above the field by a series of A-frame towers, each having two driven wheels at the base. The lateral traverses the field in a straight path creating a rectangular wetted area.

Water is discharged under pressure from sprinklers or sprayers mounted on the lateral as it sweeps across the field. As such, the evenness of application at points along the lateral, and the evenness of application as the lateral passes across the field both contribute to overall irrigation distribution uniformity.

The guidelines presented in this schedule are not intended for evaluations of linear move irrigators without overlapping sprinklers, such as the LEPA system which is not used in New Zealand.

4.6.1.1 This Schedule

This schedule outlines procedures to be followed when assessing distribution uniformity of a linear move irrigation machine fitted with overlapping sprayers or sprinklers. It was developed to provide guidelines for irrigators and others undertaking evaluations of such equipment as a 'snapshot exercise' under prevailing field conditions.

4.6.2 Special features for analysis

4.6.2.1 Stop-start operation

The speed of travel of a linear move irrigation machine is generally controlled by varying the average speed of the end tower.

For electric machines, this is achieved by cycling the power on and off using a percentage timer mounted at the pivot end. Typically the cycle time is one minute. A 25% speed is achieved by turning the end-tower drive-motor on for 15 seconds every minute (CPD, TAE).

This stop-start operation can result in non-uniform application along the travel path, especially for single irrigation events. Because the stopping points are effectively random, this is mostly mitigated by subsequent irrigation cycles (CPD).

Field evaluation should attempt to minimise effects of single event stop-start effects on distribution measurements which otherwise lead to underestimates of distribution uniformity. For a single lateral test this may require operating the machine at 100% speed to minimise the number and duration of stop-starts. Alternatively, multiple lateral or lateral/linear measurements can be used.

Hydraulically powered linear move irrigation machine run more smoothly but the possibility of erratic movement and potential effects on uniformity should be monitored.

4.6.2.2 Periodic components

The performance of a linear move irrigation machine may vary at different positions in the field or during an irrigation cycle. Contributing factors include the operation of various add-on components such as end guns that operate only part of the time.

A machine without add-on equipment, 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.

4.6.2.3 Differences between linear moves and centre pivots

The linear move discharges water uniformly along the length of the lateral, whereas the pivot discharges water at an increasing rate with distance from the centre, to account for the increase in area covered.

Linear move irrigation machines may have relatively long rotation times, compared to centre pivots which typically have a return period of only several days. This means the irrigation interval, and therefore the application depth, of a linear move is generally greater than under a pivot.

4.6.3 Technical materials

4.6.3.1 Relevant standards

ISO 11545: 2001 *Agricultural irrigation equipment – Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles – Determination of uniformity of water distribution* (ISO)

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

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

4.6.3.2 Technical references

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

4.6.3.3 Abbreviations

Reference abbreviations used in text

Cal	Burt, Walker, Styles and Parrish. 2000
IEP	Buttrose and Skewes. 1998
ISO	ISO 11545:2001
NZI	Anon. 2001
TAE	New and Fipps. 2002

4.6.3.4 Related schedules and appendices

Section 2:	Conducting a field evaluation
Schedule 3	Seasonal irrigation efficiency assessment
Schedule 4.6	Centre pivot irrigator evaluation
Appendix 5.2.2	Evaporation from collectors
Appendix 5.4	Reporting format

4.6.4 Test procedures

This schedule outlines procedures to be followed when assessing distribution uniformity of a linear move irrigation machine 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 other systems.

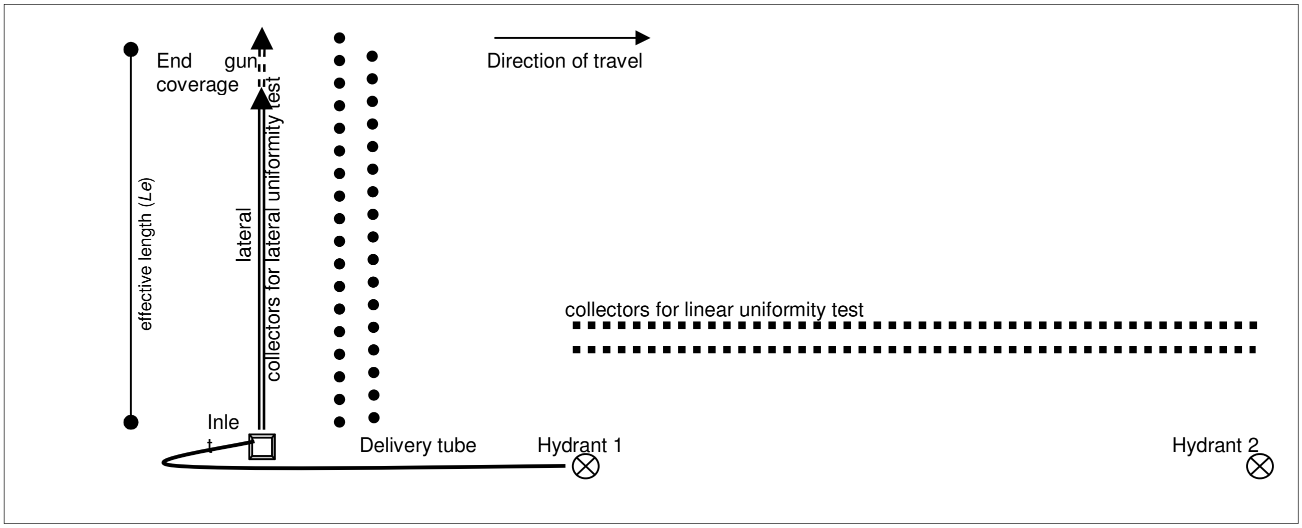

Figure 4.6.1: Collector placement for distribution uniformity test

4.6.5 Test site

4.6.5.1 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.

4.6.6 System survey

4.6.6.1 System layout

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

Mark positions where tests are to be conducted (see example Fig. 4.1.1 and Fig 4.6.1).

4.6.6.2 Machine length

Determine the machine length and the length of each span, measuring between towers.

4.6.6.3 Un-irrigated length

Determine the length of any sections of the machine excluded from irrigation.

4.6.6.4 End gun wetted radius

Determine the effective wetted radius of any end gun (or guns) fitted to the machine.

4.6.6.5 Effective length (L_e)

Determine the effective length of the irrigator as defined in Fig. 4.6.1.

4.6.7 System operation

4.6.7.1 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.

4.6.7.2 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.

4.6.7.3 Machine speed

The machine speed selected for the test should minimise the effect of stop-start effects on distribution patterns from any one-off test, and apply sufficient volume for reliable measurements to be obtained.

4.6.7.4 End gun

If the sprinkler package is designed with an end-gun, perform the test with the end gun operating. The number of sprinklers or sprayers operating should remain constant during the test.

If desired the test may also be performed with the end gun not operating in order to evaluate the water distribution under those conditions (ISO)

4.6.8 Environmental measurements

4.6.8.1 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 and the tester and client must understand the limitations of any 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).

4.6.8.2 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

4.6.8.3 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.

- Measure the elevation difference and prepare a sketch of the ground surface profile along and across the sprayline (~ISO).
- If the field is not level, measure the profile along and across the sprayline.
- Include a sketch of the profile along each line of collectors with the results unless the ground surface is level.

4.6.9 Field observations

4.6.9.1 Crop type

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

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

4.6.9.2 Crop appearance

Observe the crop for signs of stress or growth difference. Banding, striping or patchiness is indicative of poor system performance.

Measure or estimate the crop ground cover proportion.

4.6.9.3 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.

4.6.9.4 Soil properties

Determine the soil texture and depth of rooting.

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

4.6.9.5 Wheel ruts

Assess the presence and degree of wheel rutting in tower tracks. Note if water is running down wheel tracks (Cal, IEP).

Note if 'boom backs' are used or if directional sprayers are installed either side of the towers (Cal).

4.6.9.6 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.

4.6.9.7 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.

4.6.10 System checks

4.6.10.1 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.

4.6.10.2 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.

4.6.10.3 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).

4.6.10.4 Pressure regulators

If pressure regulators are fitted:

Randomly select several pressure regulators along the length of the machine and remove them for assessment of blockages. This may require dismantling the units (IEP).

4.6.10.5 Wetted radius

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

4.6.10.6 Normal speed (S_n)

Determine the typical time required to make one pass, typically a complete circuit (Cal). This may be from farmer information or design specifications.

4.6.10.7 Test speed (S_t)

Measure the machine speed in the field during the lateral uniformity test.

Mark two points on a 15 – 30m test track, positioned at random but within the last span. Time how long it takes the machine to pass over the test track, and all intermediate start and stop times (IEP).

Repeat test where speeds may be reduced because of serious rutting or other factors.

4.6.11 Flow measurement

4.6.11.1 Total machine flow

Record the water flow rate with the end-gun operating. 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.

If desired, record flow with end-gun off, waiting until flow has stabilised before taking any readings.

4.6.12 System pressure

4.6.12.1 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

4.6.12.2 Mainline pressures

[Optional Test if Problems are Identified or Anticipated]

- Measure pressure at each hydrant with irrigator operating

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

4.6.12.3 Lateral pressure

With the system operating, measure lateral 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. 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.

4.6.13 Sprinkler performance

For a linear move machine with overlapping sprayers or sprinklers, useful measurements of uniformity comes from both individual sprinkler flows and catch can collectors. Linear systems have uniform sprinkler spacings and flow rates, and the subsequent analysis allows determination of the cause of any non-uniformity (Cal).

4.6.13.1 Sprinklers/sprayers

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

If sprayers are installed, check alternate spray heads are at different elevations to avoid stream interference (IEP, Cal).

4.6.13.2 Sprinkler flow rate

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.)

4.6.13.3 Lateral uniformity test

The lateral uniformity test is of primary importance as it establishes variation along the length of the lateral pipeline. Performance is dependent on sprinkler package design and installation, field elevation and wind or other disturbances.

The easiest location for this test is along an access track, provided that area is representative of the field.

4.6.13.4 Collector placement

Paired lateral test

Arrange two rows of collectors 5m apart (fig. 4.6.1).

- Use a total of 80 collectors staggered to ensure the spacing between cans does not match sprinkler spacing. Arrange 40 collectors spaced up to 10m apart in each row.
- If an end-gun is used, the rows of collectors should be extended to just inside the effective length.

Measure and record the position of each collector relative to the machine end.

Notes:

1. Ensure the collectors are positioned ahead of the lateral, at a distance more than the wetting radius of the sprinklers so the machine is operating normally when the first water reaches the collectors. Do not place cans in wheel tracks.
2. Collection and measurement can begin once all collectors in the first wetted row no longer intercept water. This allows collection to begin as soon as possible.

4.6.13.5 Machine speed

The machine speed selected for the test should minimise the effect of stop-start effects on distribution patterns from any one-off test, and apply sufficient volume for reliable measurements to be obtained.

4.6.14 Optional tests

4.6.14.1 Repeat tests

If desired, repeat tests may be run to determine distribution uniformity without any end-gun(s) operating, or with the lateral in a different field location or locations.

4.6.14.2 Individual span tests

Tests may be run in greater detail to determine distribution uniformity under a single span. This may identify non-uniformity patterns relating to sprinkler position or overlaps, or the effects of dry-wheel packs on uniformity.

4.6.14.3 Longitudinal uniformity test

Considerable care is necessary if a longitudinal test is contemplated. Because of likely complications, this is not recommended as a standard test.

Collector placement must be extremely precise as even small displacements can give large variations due to *lateral*, rather than *longitudinal*, variation. In most cases, additional lateral uniformity tests and/or speed variation tests will give more robust results.

Linear uniformity is a measure of the application uniformity along a path in the direction of lateral travel. This provides information on how nozzle discharge and pattern varies with lateral position. The result is impacted by the amount of elevation change in the field, and effects of pressure regulators and hysteresis (CPD).

Place collectors 30m apart along the length of travel tested. For added accuracy the average catch values from a double row of collectors set 5m either side of the line can be used. Collectors in each row must be placed an exact distance from the wheel path so the same overlap contribution from adjacent nozzles is sampled at all points.

4.6.14.4 Water collection – longitudinal uniformity test

The machine speed selected for the test should minimise the effect of stop-start effects on distribution patterns from any one-off test, and apply sufficient volume for reliable measurements to be obtained.

Establish collection times to ensure evaporation losses are minimised. If the test can be run overnight, a single collection early in the morning may acceptable. Otherwise collect in sections, resetting the control collector volume each time.

A suggested schedule is 07:00, 10:00, 13:00, 15:00, 17:00, 20:00 hh (CPD).

Record the time at which the first and last measurements are made in each section.

Measure the volume remaining in the control collector after each set of readings is completed. Record the time. Reset the control collector as the wetting front leaves the next collector. Record the time.

4.6.15 Performance indicators

4.6.15.1 Distribution uniformity

A determination of field DU is a prime output from evaluations. A base value of distribution uniformity is determined from lateral distribution uniformity tests, adjusted to account for other contributing factors.

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.

4.6.15.2 Uniformity coefficient

The statistical uniformity coefficient based on Christiansen's Uniformity Co-efficient is an alternative measure that can be reported.

The uniformity co-efficient is not strictly an efficiency measurement so is reported as a decimal value.

4.6.15.3 Application depth

To make valid assessments of traveller performance, the depths measured by collectors must be adjusted to account for evaporation losses.

4.6.15.4 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.

4.6.16 System uniformity

4.6.16.1 Required adjustments

Determination of global 'field uniformity' requires that adjustments are made to account for various contributing factors, including sprinkler flow variation, distribution pattern, off target application and run-off.

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

4.6.16.2 Field distribution uniformity, FDU_{lq}

Estimate overall field distribution uniformity (FDU_{lq}). If system pressure is adequate at all points, and machine speed is uniform, the lateral DU value will suffice. If multiple collector uniformities are to be included, all depths must be pooled, and a new uniformity calculation performed with the pooled data.

Protocols for combining surface redistribution effects are, as yet, not determined.

4.6.16.3 Lateral distribution uniformity, $LatDU_{lq}$

Determine lateral low quarter distribution uniformity from adjusted application depth data using Eqn 29.

4.6.17 Other uniformity factors

4.6.17.1 Sprinkler flow uniformity, QDU_{lq}

Calculate low quarter flow distribution uniformity from sprinkler flows measured along the machine length as in 4.6.13.2 Sprinkler flow rate.

Determine the discharge uniformity of the sprinklers measured using the low quarter uniformity formula, Eqn 29.

4.6.17.2 Uniformity coefficient

Calculate the statistical uniformity coefficient for radial and longitudinal tests based on Christiansen's Uniformity Co-efficient Eqn 33.

4.6.18 Application Depth

4.6.18.1 Required adjustments

To make valid assessments of irrigator performance, the depths measured by collectors must be adjusted to account for evaporation losses.

4.6.18.2 Evaporation adjustment

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

4.6.18.3 Total machine flow application depth

Calculate application depth based on total machine flow, cycle duration and irrigated area Eqn 43.

4.6.18.4 Collector application depth

Calculate the mean application depth within the radial test zone, after adjusting for evaporation.

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

4.6.19 Application rates

The application rates under a linear move irrigator should be constant at all points in the irrigated area, including any extended areas under big-guns.

4.6.19.1 Instantaneous application rates

Calculate the maximum instantaneous application rate along the lateral using Eqn 48.

4.6.20 Pressure variation

4.6.20.1 Mainline pressures

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

4.6.20.2 Lateral pressures

Calculate lateral pressure loss, $H_L = P_{first} - P_{last}$ where P_{first} is the pressure before the first sprinkler and P_{last} is the pressure before the last sprinkler (excluding the end-gun).

As a general rule, total friction loss in the lateral of a 400m system on flat to moderately sloping ground should not exceed 70kPa (TAE).

Check that the minimum pipeline pressure is at least 20kPa (TAE) higher than the pressure regulator setting (IEP).

4.6.20.3 Pressure regulators

Pressure regulators have performance variability of about 6%. They are only recommended where pressure changes due to changes in elevation, end-gun operation or pumping lift exceed regulator variability by an amount that varies with design pressure.

In general terms, regulators are recommended if design pressure (P_d) is less than pressure variation due to elevation, pumping or end-gun operation (P_v) as given by the equation:

Fit regulators if: $P_d < (3.5\ P_v) + 3.5$

(Adapted from Allen, Keller and Martin, after Nelson Irrigation Corp 1998)

4.6.20.4 Sprinkler pressures

Determine mean pressure from measurements (4.6.13.1).

Identify any sprinklers where pressure is more than 10% different to the mean pressure.

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