4.5 Field evaluation of traveller irrigation machines

Contents

4.5.1 System description

A traveller irrigation machine irrigates a field sequentially, strip by strip by drawing a ‘gun-cart’ equipped with a water distribution system across a field.

Water is discharged under pressure from a water distribution system mounted on the as it travels across the field. A traveller is intended to be moved to, and operate from, several supply points established in advance in the field.

Irrigated strips overlap at the edges to ensure even coverage. The evenness of application across the irrigated strip, and the evenness of application as the traveller passes across the field both contribute to overall irrigation distribution uniformity.

Three broad categories are recognised each having a structure that includes a reel, spool or winch and a travelling water distribution system (FDIS).

a. Reel machines (hard hose)
Reel machines have a stationary reel anchored at the run end. The reel acts as a winch, coiling a delivery tube that both supplies water to the distribution system and drags the gun-cart along the field.

b. Traveller machines (soft hose)
Traveller machines have a cable that is anchored at the run end. The water distribution system and a travelling winch are mounted on the gun-cart. The winch pulls the gun-cart along by coiling the cable on to the reel. The gun-cart drags the delivery hose across the field.

c. Self propelled reel machines
Self propelled reel machines carry both a reel and the water distribution system and draw themselves across the field by coiling the anchored delivery tube on to the reel.

In addition, there are three different water distribution mechanisms; big gun, fixed boom and rotating boom. Each of these requires slightly different evaluation procedures to identify causes on non-uniformity.

Traveller irrigation machines make irrigation feasible in many areas where other techniques are not suitable. They are easily transported between fields even over relatively long distances, and can be used to irrigate irregularly shaped areas.

4.5.1.1 This Schedule

This schedule outlines procedures to be followed when assessing distribution uniformity of a traveller irrigation machine 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.

Recommendations for planning, conducting and reporting on distribution uniformity assessments are intended to promote efficient work practices and informative reporting that facilitates easy comparison of systems. The procedures outlined will provide a satisfactory level of accuracy, and identify causes of non-uniformity and the contribution each makes to the overall performance of the system.

4.5.2 Special features for analysis

4.5.2.1 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 machine’s performance is measured for one set position, and measurements from outer edges mapped on to the corresponding measurements on the opposite side.

4.5.2.2 Changing travel speed

The speed of a travelling irrigation machine may change as successive layers are laid upon the reel or winch, or because ground conditions create different amounts of drag on the gun-cart.

Field evaluations can estimate the effect of varying travel speeds on distribution uniformity by making multiple transverse measurements and completing a longitudinal speed assessment.

4.5.2.3 Wind effects

The performance of a travelling irrigation machine can be greatly affected by wind, particularly when gun-type nozzles are used on high angle settings.

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.

4.5.2.4 Field variability

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

A machine 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.

4.5.2.5 High operating pressures

Relatively high operating pressures, particularly for big guns, minimises the effect of terrain pressure change effects on flow or distribution pattern

4.5.2.6 Stationary operation

Travelling irrigators may be operated stationary at either end of the strip to ensure at least the target application depth is applied. This increased losses by deep drainage from the section of the wetted area that is ‘over watered’. Field uniformity and application efficiency are reduced, more so on short runs.

4.5.3 Technical materials

4.5.3.1 Relevant standards

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

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

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

4.5.3.2 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)

4.5.3.3 Abbreviations

Reference abbreviations used in text

FDIS ISO/FDIS 8224-1:2002

ISO ISO 11545:2001

4.5.3.4 Related schedules and appendices

Section 2: Conducting a field evaluation

Schedule 3 Seasonal irrigation efficiency assessment

Appendix 5.2.2 Evaporation from collectors

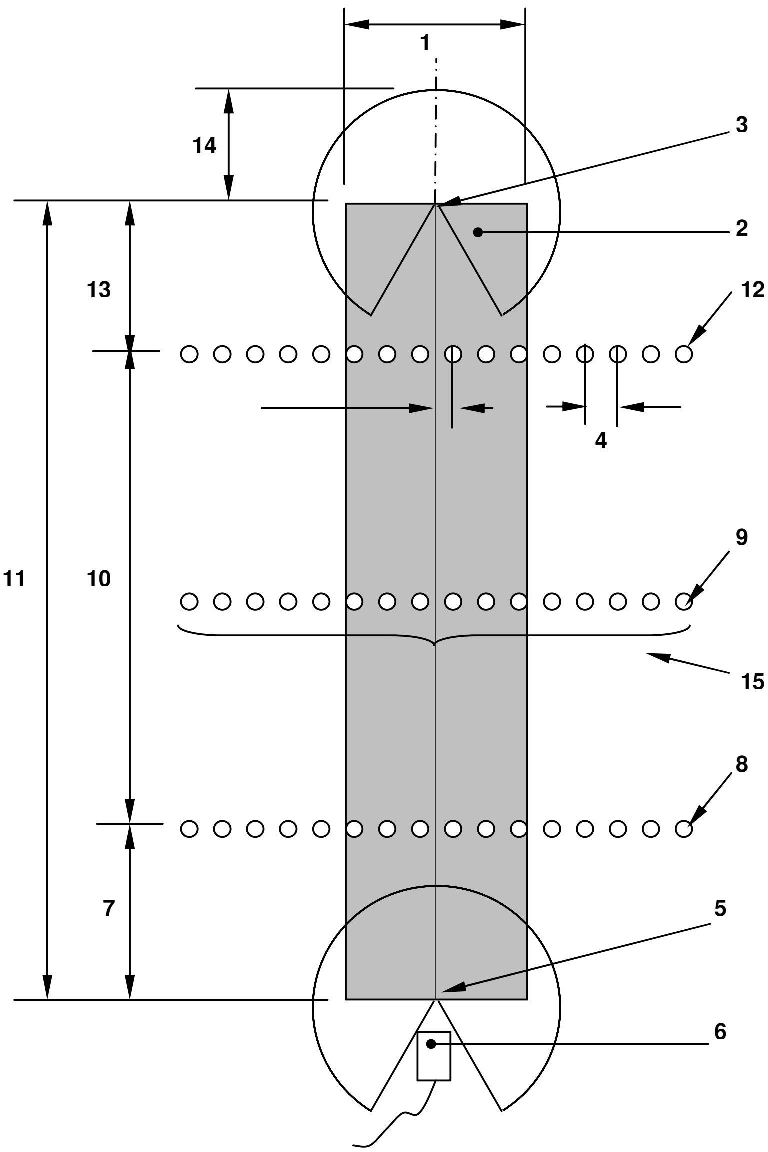
Appendix 5.2.3 Overlapping systems

Appendix 5.4 Reporting format

4.5.4 Test procedures

This schedule outlines procedures to be followed when assessing distribution uniformity of traveller irrigation machines 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*
2 Irrigation strip accounting for overlap
3 Distribution system; initial position
4 collector spacing, s_c
5 Distribution system: final stop position
6 fixed end of travelling irrigation machine
7 end guard > wetted radius (14)
8 position of last line of collectors, *n*
9 position of intermediate line of collectors, *i*
10 transverse line layout zone (>50% L_t)
11 length of strip, travel path length, L_t
12 position of first line of collectors, *1*
13 end guard greater than wetted radius 14
14 distribution system wetted radius, r_w
15 extension of collector lines

Fig 4.5.1: Field collector layout [From ISO/FDIS 8224-1:2002]

4.5.5 Test site

4.5.5.1 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.

4.5.6 System survey

4.5.6.1 System layout

Prepare a map of the system recording the headworks, mainline, and hydrants (take-off points).

Mark positions where tests are to be conducted (see example Fig 4.5.1).

4.5.6.2 Irrigation strip

Measure the irrigation strip length and width, and travel path length as defined in Fig 4.5.1.

4.5.6.3 Off-target application (F_{target})

Estimate the proportion of discharge that falls outside the target area for a single run and the field as a whole. For a single run this includes discharge beyond the ends of the irrigated strip. For the field as a whole the outside edges of the first and last strips will also be included.

4.5.7 System operation

4.5.7.1 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.

4.5.7.2 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.

4.5.7.3 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.

4.5.7.4 Machine speed

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

4.5.8 Environmental measurements

4.5.8.1 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.

4.5.8.2 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

4.5.8.3 Topography

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

- Measure the elevation difference and prepare a sketch of the ground surface profile along and across the irrigated strip (~ISO).
- Include a sketch of the profile along each line of collectors with the results unless the ground surface is level.

4.5.9 Field observations

4.5.9.1 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.

4.5.9.2 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.

4.5.9.3 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.

4.5.9.4 Soil properties

Determine the soil texture and depth of rooting.

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

4.5.9.5 Wheel ruts

Assess the presence and degree of wheel or skid rutting in the travel path (FDIS). Assess if machine speed is likely to be affected by ruts.

4.5.9.6 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.

4.5.9.7 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.

4.5.10 System checks

4.5.10.1 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.

4.5.10.2 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.

4.5.10.3 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).

4.5.10.4 Guns

Record the nozzle age, type and orifice(s) fitted

Measure the diameter of the orifice and assess for wear

Record the vertical and sector angle settings

4.5.10.5 Fixed booms

Record the nozzle age, type(s) and orifice(s) fitted

Randomly select a number of sprinklers or sprayers along the length of a fixed boom. 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).

4.5.10.6 Rotating booms

Record the nozzle age, type(s) and orifice(s) fitted

Assess nozzle orifices for wear

Ensure boom rotation is correct and unhindered.

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

4.5.10.7 Machine speed

The uniformity of speed along the path of travel can affect the field uniformity.

Measurement of travel speed at intervals along the path can identify a potential cause of non-uniformity, and is needed to compare machine flow rates and measured application rates.

4.5.10.8 Stationary operation (T_s)

Measure the time the machine is operated stationary at the beginning and at the end of the strip.

4.5.10.9 Transverse test speeds (S_t)

Measure the machine test speed in the field as the machine passes over collectors used for each transverse application uniformity assessment.

- As the wetting zone reaches each line of collectors, mark a point on the delivery tube (hose) or winch cable, and mark the corresponding point in the field with a peg. Record the time.
- When the wetting zone no longer reaches any collectors in the line, place a second peg in the ground corresponding to the mark on the tube, and record the time.
- Measure the distance between the two pegs and calculate the travel speed.

4.5.10.10 Longitudinal speed uniformity (S_l)

Establish a sample of segments, each 5m long, along the travel path. There should be at least one segment for each layer of delivery tube or cable on the winch reel.

Record the location of each segment as the distance of the gun-cart from the final end point of the strip.

Calculate segment travel speed for each segment by dividing the segment length by the corresponding time taken for the gun-cart to pass over it (FDIS).

Determine the mean travel speed along the travel path from the total time required to travel the strip length. Do not include any time operating stationary at either end (FDIS).

4.5.11 Flow measurement

4.5.11.1 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.

4.5.11.2 Energy use

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

4.5.12 Pressure measurement

4.5.12.1 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

4.5.12.2 Mainline pressures

[Optional test if problems identified or anticipated.]

For moveable machines or systems, measure pressure at each hydrant

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

4.5.12.3 Machine pressures

With the system operating, measure pressures:

- At the inlet to the machine (FDIS).
- At the inlet and outlet to the hydrodynamic drive (FDIS).

4.5.12.4 Sprinkler pressure

Measure pressure at the inlet to the gun or sprinkler package.

4.5.13 Sprinkler performance

A wide variety of water distribution systems may be fitted to travelling irrigators. Three different types are recognised; guns, fixed booms and rotating booms.

4.5.13.1 Guns

With machine stationary (system operating)

Determine the wetted radius of the water distribution system to the nearest 10cm for three radii: in-line with, and at 90^o angles left and right of, the direction of travel.

4.5.13.2 Fixed booms

With machine stationary (system operating)

Determine the wetted length of the water distribution system to the nearest 10cm (~FDIS).

Measure the flows from 12 sprinklers chosen at random along the length of the boom. 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 pipe or 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.

4.5.13.3 Rotating booms

With machine stationary (system operating)

Determine the wetted radius of the water distribution system to the nearest 10cm for three radii: in-line with, and at 90^o angles left and right of, the direction of travel.

Because the contribution individual sprinklers make to distribution patterns cannot be distinguished, sprinkler measurements are not made.

4.5.13.4 Transverse uniformity test

The transverse uniformity test is of primary importance as it establishes variation across the irrigated strip. Performance is dependent on sprinkler package design and installation, field topography and wind or other disturbances.

Arrange three lines of collectors perpendicular to the delivery tube (hose) or tow cable (**Fig 4.5.1**).

- For reel irrigation machines, establish each transverse line such that different numbers of layers of delivery tube are coiled on the reel.

Ensure the distance between first and last lines is at least 50% of travel length (L_t).

- Ensure the first line of collectors is positioned ahead of the irrigator, at a distance more than the wetting radius of the water distribution system so the machine is operating normally when the first water reaches the collectors.
- Ensure the last line is positioned at a distance more than the wetting radius of the water distribution system so water stops reaching the collectors before the machine becomes stationary.

4.5.13.5 Collector placement

Select collector spacing (s_c) such that the half width of the irrigated strip is a multiple of the collector spacing.

- E.g. If E = 90m, E/2 = 45m. Select a collector spacing of 3.0, 4.5 or 5.0 m.
- The maximum spacing between collectors should be 6m for guns and 3m for sprayers or sprinklers.

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.

- Do not place collectors in wheel tracks.

Measure and record the position of each collector relative to centre of the travel path.

4.5.13.6 Evaporation

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 each transverse line as the irrigator passes, resetting the control collector volume each time.

4.5.14 Optional tests

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

4.5.15 Performance indicators

4.5.15.1 Distribution uniformity

A determination of field DU is a prime output from evaluations. Distribution uniformity from multiple transect tests is adjusted to account for other contributing factors including run=off and off-target application.

Distribution uniformity is not strictly an efficiency measurement so is reported as a decimal value.

4.5.15.2 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.

4.5.15.3 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.

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

4.5.15.4 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.

The application rate under the immediate wetting area of a big gun may be very high, but as it occurs for only as very short time is generally within reasonable infiltration limits.

4.5.16 System uniformity

4.5.16.1 Required adjustments

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.

4.5.16.2 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 grid distribution uniformity of the distribution system (gun or boom) assessed from overlapped multiple transect uniformity tests. It may be adjusted for run-off or off-target application.

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

Where:

FDU_{lq} is low quarter field distribution uniformity

GDU_{lq} is low quarter grid distribution uniformity (multiple transects)

$F_{ponding}$ is redistribution from surface ponding

4.5.16.3 Grid distribution uniformity, GDU_{lq}

Create a virtual grid comprising all transect tests.

Adjust 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} from all adjusted depths from all transects using Eqn 29.

4.5.16.4 Off-target factor

Calculate an adjustment factor for off-target application and field runoff from estimates of the percentage of total take represented by these contributing factors.

4.5.16.5 Flow distribution uniformity, QDU_{lq} (Fixed boom systems only)

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

4.5.17 Other uniformity factors

4.5.17.1 Uniformity from alternate sets

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

Determine alternate set uniformity by overlaying left side collector data on the right side data, as described in 5.2.3 .

4.5.18 Application Depth

4.5.18.1 Required adjustments

To make valid assessments of travelling irrigator performance, the depths measured by collectors must be adjusted to account for evaporation losses and for the effect of overlaps from adjacent irrigation runs (strips).

4.5.18.2 Evaporation adjustment

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

4.5.18.3 Overlap accounting

For water distribution systems intended to operate with areas of overlap, application depths must be adjusted to account for overlap effects.

Account for overlap as described in Appendix 5.2.3 Overlapping systems .

4.5.18.4 Total machine application depth

The application depth based on total machine flow, cycle duration and irrigated area is calculated using Eqn 51.

This assumes that each strip is overlapped from each side, so each strip receives the full volume of water applied during one travel run.

4.5.18.5 Transverse line application depth

Calculate the mean application depth within the wetted strip for each transverse line, after adjusting for evaporation and overlap.

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

4.5.18.6 Wetted strip application depth

Calculate mean application depths for the strip as the mean of the transverse line adjusted depths.

Determine the overall minimum and maximum application depths.

4.5.19 Application rates

The instantaneous application rates under traveller irrigation machines may be very high. High instantaneous application rates can lead to ponding and surface redistribution.

However with guns or rotating booms, any area is watered for only very short periods each rotation, so soil infiltration will often accept these rates. Under fixed booms the area is watered continuously and ponding may be more apparent.

4.5.19.1 Instantaneous application rate

Calculate the mean application rate (mm/h) for each transect from mean adjusted applied depths, travel speed and the wetting area of the distribution system, using Eqn 47.

The maximum application rate at central points will typically be greater than the average overall application rate as the rate reduces toward the edge of the wetted strip.

4.5.19.2 Wetting area of distribution system

Fixed boom

The wetting area of a fixed boom is mean sprinkler wetted diameter times effective width of the boom.

Rotating boom

The wetting area of a rotating boom is area of a circle based on effective wetting diameter of boom

Big Gun

The wetting area of a big gun can be estimated as half the area of a circle based on the effective wetted radius of the gun trajectory.

4.5.20 Machine speed

4.5.20.1 Travel speed at transverse lines

Determine the travel speed at each transverse line (Eqn 50).

4.5.20.2 Speed of travelling irrigator

Calculate the speed at each segment (m/h) using Eqn 50.

Determine the mean speed by dividing the full strip length (m) by the time taken to water the strip (hours) excluding any stationary time at either end.

Determine the mean, the maximum and minimum speeds.

4.5.21 Additional determinations

4.5.21.1 Mainline pressures

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

4.5.21.2 Fixed boom sprinkler discharge

Calculate mean discharge from the 12 measured sprinklers as described in 4.5.13.2 Fixed booms

4.5.21.3 Longitudinal speed uniformity

Determine the maximum deviation in travel speed using Eqn 51.

Determine the coefficient of variation in travel speed using Eqn 20

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