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IRRIGATION NEW ZEALAND INC

Irrigation Evaluation Code of Practice

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NOTE: This Code is paired with the Code of Practice for Irrigation Design.

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Address for Comments

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Section 4.7 Centre Pivot amended – remove Circular Test Recommendation

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1 Introduction

1.1 Introducing the Code of Practice for Irrigation Evaluation

Low irrigation efficiency has negative impacts on farm profitability, economic prosperity and the environment. Poorly performing (non-uniform) irrigation systems and poor scheduling have been identified as the major causes of low efficiency and subsequent waste of water and energy.

Without tools to assess actual system performance, irrigators and other stakeholders are not able to determine or benchmark performance. The Code of Practice for Irrigation Evaluation provides nationally recognised and widely accepted guidelines that can be used to demonstrate and improve the efficiency of irrigation.

Adoption of this Code will enable cost effective, defensible assessments of irrigation systems and scheduling performance, and provide recommendations for improvement. This will directly benefit irrigators, the environment and the community.

The Code of Practice for Irrigation Evaluation was prepared by Page Bloomer Associates Ltd under Sustainable Farming Fund Project 02-051. Development was jointly funded by the Sustainable Farming Fund, Hawke's Bay Regional Council, Pipfruit New Zealand, Environment Canterbury, the Foundation for Arable Research and the Vegetable Growers' Federation Process Sector.

1.1.1 Why a code was developed

The Code of Practice for Irrigation Evaluation was developed to provide guidelines for irrigators and others undertaking evaluations of irrigation systems in the field. It makes recommendations for planning and conducting evaluations and reporting on the performance of irrigation systems and their management. Its focus is on key performance indicators established in the Code of Practice for Irrigation Design 2004 (draft).

The Code has been developed with reference to international practices and standards, including the draft NZ Code of Practice for Irrigation Design. The main aim of the guidelines is to encourage adoption of standardised evaluation practices that are cost-effective, recommendation driven and encourage more efficient use of irrigation resources. Its adoption will provide irrigators, regulators and other stakeholders with confidence that findings are valid, repeatable and comparable.

The Code of Practice for Irrigation Evaluation is designed to guide irrigation system and management evaluations that recognise the unique character of individual farms, their irrigation requirements and constraints, yet provide for valid comparisons and allow benchmarking of performance.

This approach is based on that developed by the Irrigation Training and Research Center (ITRC), California Polytechnic State University, California, and various ISO and ASAE Standards.

1.1.2 The reason for having a code

Irrigation is beneficial to agriculture, to the economy and to our communities. To maximise the benefits of irrigation, water application must be made correctly with an understanding of what is taking place. Good irrigation system performance and good management of those systems are fundamental to efficient use of a strictly limited resource.

As the largest user of water in New Zealand, the irrigation industry understands that it has an obligation to manage water in a responsible manner and to recognise the rights of other users. This code will assist irrigators to ensure and demonstrate that the impact of their irrigation activities on the environment is minimised.

Evaluating irrigation systems and their management is a way for members of the irrigation industry to demonstrate their responsible attitude towards land and water resources, and to show that their practice matches or exceeds accepted community values. Evaluations are valuable additions to environmental quality assurance systems which are essential if export and local market access is to be maintained.

With irrigation accounting for 70% of all water used in New Zealand, and contributing an estimated $920 million dollars to GDP in 2002/03 (Doak et al 2004), the Code makes a significant contribution to sustainable management practices throughout the country.

1.1.3 Legitimacy

1.1.3.1 Are these guidelines compulsory?

This Code is not a regulation. It recognises the right of individuals to make their own business decisions, provided these decisions comply with legal requirements, regulations and industry standards. These decisions should also comply with principles of preserving natural resources.

On the other hand it is recommended that irrigation evaluators and other stakeholders take this Code into account, because following these guidelines will provide confidence to irrigators, other evaluators, regulators and stakeholders that the findings are valid and comparable.

1.1.4 Authorities overseeing the code

1.1.4.1 Code of Practice for Irrigation Evaluation

This Code is overseen by Irrigation New Zealand Inc. Unless otherwise stated, guidelines presented in this Code are the responsibility of Irrigation New Zealand Inc.

1.1.4.2 Technical Standards and Guidelines

Standards and guidelines from other Codes of Practice that are referenced within the Code are overseen by the relevant issuing authority.

1.1.5 Certification

There are two parallel and complementary certification programmes referenced by this Code.

The National Certificate in Irrigation Evaluation is registered on the National Qualifications Framework of the New Zealand Qualifications Authority (NZQA) through the Agricultural Industry Training Organisation.

The Certified Agricultural Irrigation Evaluator programme is run under the auspices of Irrigation New Zealand Inc.

1.1.6 Consultation Process

Organisations and stakeholders consulted in the preparation of this Code of Practice include:

Irrigation New Zealand

Pipfruit NZ Inc

NZ Vegetable & Potato Growers' Fed

Foundation for Arable Research

Hawke's Bay Regional Council

Environment Canterbury

Hydro-Services Ltd.

Winegrowers of New Zealand

New Zealand Turf Institute

Dairy Insight

Lincoln Environmental

Zespri

Water Dynamics

Water Control Solutions

MAF Policy

1.1.7 What is in the code

1.1.7.1 Part 1 Introduction

This code is a written statement of the minimum desirable practices and actions to undertake when conducting irrigation system evaluations in the field for the purpose of improving performance. The code presents practices of an acceptable standard, given the current state of knowledge.

1.1.7.2 Part 2 Conducting evaluations

Part Two of the Code outlines procedures for conducting efficient and reliable irrigation evaluations, and addresses skills and qualifications for irrigation system evaluators.

Those undertaking system evaluations according to the guidelines outlined in this Code of Practice and associated Standards must have the skills and knowledge of their application. The clients of those conducting evaluations require evidence of competence, and surety that the evaluation has been conducted in a way that is fair and representative, by a practitioner with appropriate skills and integrity.

The base training and certification programme is the National Certificate in Irrigation Evaluation. This is run under the auspices of the New Zealand Qualifications Authority (NZQA) through the Agricultural Industry Training Organisation. A professional Practising Certification programme is being developed by the Irrigation New Zealand Inc.

1.1.7.3 Parts 3 and 4 Technical Schedules

Parts Three and Four of the Code present a series of Schedules for Irrigation Evaluation.

To ensure results obtained by one evaluator are valid and are comparable to those of another, standard procedures and assessments have been developed. These schedules are the components that form the basis of any irrigation evaluation completed as prescribed in this Code.

Schedule 3.1 relates to determinations of irrigation efficiency, assessed in terms of seasonal application efficiency, potential soil moisture deficit and deep percolation resulting from irrigation.

Schedules 4.1 – 4.7 outline procedures for on-site evaluation of system performance. Covering a range of pressurised irrigation types, the main purposes of these evaluations are: to determine actual application rates, to determine ‘global’ irrigation system distribution uniformity, and to identify the causes and relative importance of various factors contributing to non-uniformity.

System types covered include drip-micro irrigation, solid set, spraylines, multiple lateral spraylines, travelling irrigators, linear move and centre pivot irrigators. Surface irrigation methods, such as furrow or border dyke systems, are not presently covered by this Code.

1.1.7.4 Part 5 Appendices

Part Five of the Code is the Appendices. These contain selected reference material including definitions, formulae, equipment, and measurement specifications.

A series of templates are provided for use when conducting on-farm irrigation evaluations. These templates are designed to interface with prepared software that performs required calculations and generates standard reports.

1.1.8 What is not in the Code

This code applies only to evaluations of pressurised systems, performed on-site under prevailing conditions. These should reflect typical operating conditions for that system under the current management regime. The level of implicit statistical error resulting from selected methodologies must be noted. No evaluation result can be claimed to have an error of less than ± 5%. In some cases it may be significantly larger.

The Code does not cover laboratory testing undertaken to validate the design or construction of a particular make or model of irrigation machine. It does not apply to assessments of irrigation equipment for the purposes of supplying generic design information. Those activities should be guided by the relevant existing standards such as those prepared and published by the International Organisation for Standardisation.

1.2 Acknowledgements

The Code of Practice for On-Farm Irrigation Evaluation was prepared under Sustainable Farming Fund Project 02-051 as a joint project funded largely by the Ministry of Agriculture and Forestry through the Sustainable Farming Fund.

Financial and in-kind contributions were received from:

Pipfruit NZ Inc

Hawke's Bay Regional Council

NZ Vegetable and Potato Growers' Federation

Foundation for Arable Research

Environment Canterbury

Hydro-Services Ltd

In-kind support was provided by:

Winegrowers of New Zealand

Agriculture Industry Training Organisation

Agribusiness Training Ltd

Members, Irrigation New Zealand Inc

Additional support was received internationally from:

California Polytechnic State University, (CalPoly) San Luis Obispo, CA. USA

Primary Industries and Resources, South Australia

Center for Irrigation Technology, Fresno, CA. USA

The Irrigation Association (USA)

Irrigation Association of Australia

Cemagref, France

ISO Technical Subcommittee ISO/TC 23, SC18: Irrigation and drainage equipment and systems

Technical development was provided by:

Page Bloomer Associates Ltd

Pink House Software Ltd

2 Conducting irrigation evaluations

Contents

2.1 Introduction

This section outlines procedures for conducting efficient and reliable irrigation evaluations, and addresses skills and qualifications for irrigation system evaluators.

An irrigation evaluation may be carried out for any of several reasons. In each case, objective information is sought that will allow analysis of performance. This may be used to identify problems, enhance performance, or to demonstrate compliance with regulatory or market requirements.

2.1.1 Evaluations and audits

The words ‘evaluation’ and ‘audit’ are often used, but without clear or agreed definitions.

Commonly, an ‘*audit*’ is considered to be an independently conducted comparison of measured performance against some previously specified set of parameters for possible consideration by some third party.

A definition equivalent to Environmental Management System Audit as defined in ISO 14 050 is, “The systematic and documented verification process of objectively obtaining and evaluating audit evidence to determine whether an [irrigation] system conforms to the [irrigation] system audit criteria, and communicating the results of this process to the client.”

The implicit intent of an ‘*evaluation*’ is to provide information for management decision making. There is no assumption that findings will be made available to or used by a third party, and as such, an evaluation may be considered a less official exercise.

To the extent that these ‘evaluation’ procedures objectively measure irrigation systems and management against the Key Performance Indicators established in the (draft) Code of Practice for Irrigation Design, and may be submitted for consideration by some third party, they can be considered outlines for an audit.

2.1.2 On-site evaluations

An on-site evaluation of an irrigation system utilises selected measurements to describe performance of the system and its management, and to identify causes of poor performance and how these may be addressed. Actual measurements are used wherever possible. This ensures that the generated results describe what is happening, not what is supposed to happen.

This section describes the procedures to follow when planning, conducting and reporting on evaluations. Procedures are based on key site measurements and mathematical analyses to generate descriptions of system performance.

In determining some parameters, in particular distribution uniformity, stratified or targeted sampling approaches are used in preference to strict randomised sampling. This allows analysis not only of system performance, but also of the factors contributing to non-performance. In practice, this has been shown to give similar results to randomised sampling, but in any case, limitations and confidence levels should be recognised.

2.1.3 Why these schedules were developed

These schedules were developed to provide guidelines for people undertaking evaluations of irrigation systems as a ‘snapshot exercise’ under prevailing field conditions. They are intended to promote efficient work practices and informative reporting that facilitates easy comparison of systems.

The schedules have been developed with reference to international practices and standards. Those standards each prescribe different procedures and sampling methods that are not necessarily equivalent. This schedule attempts to encompass all minimum requirements but ensures that procedures are practical for implementation in a cost effective on-site evaluation. Evaluators undertaking assessments for other purposes should be familiar with the relevant international Code or Standard and select that which is appropriate to their intent.

The procedures outlined will provide a satisfactory level of accuracy, identify causes of non-performance and the contribution each makes to the overall performance of the system. Adoption of these guidelines will provide irrigators, regulators and other stakeholders with confidence that findings are valid, repeatable and comparable.

2.1.4 Evaluation process

Irrigation evaluation follows a set of procedures that objectively check an irrigation system and management practices, and allows a system to be benchmarked against established standards. Irrigation maintenance and management plans can then be drawn up to improve the system and save money.

The steps in conducting an evaluation are:

- Decision to conduct an evaluation
- Decision on aspects to be investigated
- Appointment of an Evaluator
- Provision of base information
- Document analysis
- On-farm measurements
- System analysis
- Reporting
- Management decisions
- System and operating changes

2.1.5 Planning an evaluation

The evaluation process will be greatly assisted if appropriate preparations are made prior to visiting the field. These preparations include collection of relevant data about the system and its management, ensuring all required equipment is available, and that the system will be ready for testing when the evaluator arrives at the field.

By following a plan such as that laid out below, evaluations should be carried out as efficiently as possible with a minimum of delays.

2.1.5.1 Typical irrigation evaluation

A typical Irrigation Evaluation consists of:

- A visual inspection plus a uniformity test on the system to determine the water application efficiency over the site
- A seasonal irrigation efficiency estimation
- Assessment of pump, pipe and filter performance including energy use

Each of these components involves evaluating the system or management practices in their current state. Analysis and reporting of results compares these results to some specified standard, and makes recommendations for improvement.

The evaluation is only the start of the process towards irrigation “best practice”. It is important that managers use the generated information to develop irrigation management and maintenance programmes that continuously improve the irrigation system and practice.

2.1.6 Information Needs

Assuming this evaluation will be part of a full system analysis, much of the required information can be obtained from a general irrigation questionnaire completed by the irrigator.

Information that should be obtained prior to conducting an evaluation may include:

2.1.6.1 General property information

- Owner/Contact name and details
- Property location and address
- Property plan, aerial photos, contour map
- Enterprises

2.1.6.2 Climate information

- Long term rainfall data
- Long term ET data
- Current or Last Season rainfall
- Current or Last Season ET

2.1.6.3 Soils information

- District/property soil maps
- Soil texture
- Soil water holding capacity data
- Soil limitations

2.1.6.4 Farm water supply information

- Water source and quality
- Resource consent limits and conditions
- Overall system layout
- Total flows
- Filtration type

2.1.6.5 Irrigation system information

- Permanent system layout
- Movable system positions
- Age and condition
- Connection to farm water supply
- Irrigation machine type
- Motive power and operating speed
- Controller location
- Operating instructions
- Design flow
- Operating pressure
- Sprinkler package
- Whether other water takes influence the system

2.1.6.6 Irrigation management information

- Irrigation need monitoring
- Irrigation interval (rotation length)
- Irrigation duration
- Target application depth

2.1.7 Visit planning

The irrigation system owner or manager is needed to confirm that the machine and field visited are the ones intended for evaluation, to identify any hazards or other on-site issues and to clarify or fill in information missing from pre-visit questionnaire(s).

There are benefits in the usual system operator being involved in the evaluation process, to operate the equipment (as usual), and to understand the evaluation process.

Agreements to be obtained prior to the visit include:

2.1.7.1 Evaluation date(s)

- Setting a date, time and meeting place
- Ensuring any required staff will be present and available

2.1.7.2 Service and fees

- Confirming evaluation(s) to be conducted
- Establishing how results will be reported
- Establishing fee for service

2.1.7.3 System availability

- Ensuring the system will be available for evaluation
- Ensuring any system maintenance has been completed
- Ensuring access to irrigation system, equipment and suitable field

2.1.8 Equipment needs

The equipment required to determine distribution uniformity is very similar, regardless of the system being assessed.

Specifications for tools or equipment that may be required are noted in the Appendix 5.3.

2.2 Conducting an evaluation

2.2.1.1 Meet the irrigator

Ideally the owner/manager should be present during the evaluation, to ensure the equipment is operated correctly, consistent with usual practice. The owner/manager should make adjustments or alterations to the machine, and provide assistance if required. The owner/manager should take responsibility for any jobs that involve tampering with the irrigation system, such as fitting pressure gauges or flow meters.

2.2.1.2 Confirm questionnaire responses

In consultation with owner/manager:

- Review pre-visit questionnaire responses
- Fill in missing details as required
- Review or draft property and system plans

2.2.1.3 Confirm evaluation details

In consultation with owner/manager:

- Confirm purpose of evaluation
- Confirm normal and test operating conditions
- Locate key features and components in the field
- Select test locations and test to be conducted

2.2.1.4 Conduct pre-test inspection

- Observe crop growth patterns and record abnormalities
- Assess soil condition, root depth and estimate water holding capacity
- Assess wheel track condition on moving systems
- Familiarise with system layout and components
- Measure and record topography if variable, focusing on key system points

2.2.1.5 Set-up test equipment

- Install temporary flow meter if used
- Fit pressure test points as required
- Determine location for, and set out, evaporation collectors
- Set out speed test markers
- Establish weather monitoring location and equipment

2.2.1.6 Pre-start checks

- Take water meter readings
- Take power meter readings
- Check headworks components and layout as prescribed
- Assess filter condition and record contaminant type and amount
- Check sprinkler package is correctly installed
- Assess sprinklers or emitters for blockages or wear

2.2.1.7 Operating checks

The owner/manager should operate the system, including automatic controllers and motor starting.

- With system operating check flow rates measured by water meter
- Check for correct equipment functioning
- Measure un-irrigated machine or boom lengths
- Record system pressures at prescribed locations
- Assess surface ponding
- Assess for crop interference
- Assess leakages and off-target applications
- Conduct machine speed tests as required

2.2.1.8 Sprinkler/outlet checks

- Check sprinkler or other outlet operation and record abnormalities
- Measure outlet flows as prescribed
- Determine wetting radius of sprinkler package and/or end-guns etc

2.2.1.9 Uniformity testing

- Record key weather conditions throughout test period
- Lay-out uniformity collectors according to test arrangement
- Collect applied water in collectors
- Charge evaporation collectors as soon as collector volume measurement begins and record volume and time
- Immediately collectors stop receiving water, begin collection measurements, recording the time for each reading
- At completion, record evaporation collector volumes and the time

2.2.1.10 Specific tests

- Conduct any tests specific to the irrigation system type or evaluation

Examples may include:

- Alternative pressure/flow tests for micro-irrigation systems
- Specific span tests on pivot or linear systems
- Alternative gun-angle tests on travellers

2.2.1.11 Post-test checks

- Take flow meter readings
- Take power meter readings
- Observe system drainage patterns

2.2.1.12 Pre-leaving checks

- Ensure all readings have been made and recorded
- Ensure equipment is recovered and the system returned to pre-test condition
- Ensure system is closed down as required (ideally an owner/manager responsibility)

2.3 Data analysis

Much of the data analysis requires repetitive and relatively complex calculation. For this reason the use of prepared software is recommended.

2.3.1.1 Software

Supporting software packages are available from a variety of sources. These prompt evaluators to make and record particular measurements or assessments, assist with the calculations, and generate reports and recommendations based on inputted values.

The various software packages may not use the same units as those prescribed in these guidelines, and may be based on different procedures of sampling methods. If these factors are noted, most can be adapted to the requirements outlined in this schedule.

In New Zealand, the IRRIG8 Irrigation Evaluation program was developed to support evaluations undertaken in accordance with this Code.

2.3.1.2 Determine system performance

- Process collected data as prescribed to calculate the key performance indicators for the system as tested
- Complete other system analyses as required
- Compare results to benchmark values
- Identify key causes on non-performance
- Assess the contribution of factors to overall performance

2.3.1.3 Determine seasonal efficiency

- Process questionnaire responses to assess the adequacy and efficiency of irrigations for the preceding season
- Estimate the cost savings that may be achieved from system and/or management improvements
- Estimate yield losses and values resulting from inadequate irrigation

2.4 Report preparation

The purpose of reports is to provide the system owner/manager with information to help improve performance.

- Present key performance indicators as prescribed
- Present conclusions and comparisons with established performance benchmarks
- Present recommendations
- Present performance data graphically where appropriate
- Include base data and calculations in appendices

2.5 Technical Schedules

The technical schedules provide guidelines for the assessment of both individual irrigation system performance and overall seasonal irrigation efficiency. These are intended to allow irrigators and other stakeholders to determine and benchmark performance, and to identify problem areas and the contribution these make to overall system in-efficiency.

2.5.1.1 Key performance indicators

Key performance indicators are presented in the Code of Practice for Irrigation Design (2004). They include:

Water Use Efficiency

- Crop irrigation demand
- Management allowable deficit
- Return interval
- Application uniformity
- Application rate
- Application depth
- Adequacy of irrigation
- Application efficiency
- Distribution efficiency
- Headwork efficiency
- Supply reliability
- System capacity

Other Efficiency Indicators

- Energy
- Labour
- Capital
    - Capital cost
    - Operating cost
- Effectiveness
- Productivity
- Returns
- Environment
    - Average system efficiency
    - Drainage
    - Runoff

Indicators selected for this Code relate to estimates of efficiency across an irrigated growing season or year. They provide information relating to economic or environmental implications of in-efficient irrigation systems or management.

2.5.2 Seasonal Irrigation Efficiency

Schedule 3 Seasonal Irrigation Efficiency outlines procedures for estimating measures of seasonal irrigation efficiency (SIE).

The indicators estimate the effectiveness and efficiency of irrigation scheduling on a seasonal basis. They are calculated using soil moisture budgets; tracing inputs and outputs from a conceptual reservoir of some set size.

The schedule identifies varying levels of analysis ranging from very simplistic to highly detailed. The simplest is a quick estimate of Seasonal Irrigation Efficiency based on comparing total seasonal irrigation and rainfall with total estimated seasonal evapo-transpiration.

A more detailed process is recommended where information is available. Therefore the schedule outlines a process for more detailed analysis, requiring knowledge of soil water properties, seasonal weather, potential crop water use, and irrigation system performance and management.

2.5.3 System performance

Schedule 4 outlines procedures to determine irrigation system performance, on-site, under prevailing crop and weather conditions. The primary focus is to determine distribution uniformity and application rates, and identify the proportional contribution key factors make to non-uniformity.

Additional procedures are presented in some cases. The option(s) selected by an evaluator will depend upon the purpose of the evaluation. This should always be discussed with the system owner and person requesting the evaluation be undertaken.

2.5.3.1 Application of schedules

These schedules can be used as standalone guidelines for determining irrigation system performance in the field. They are intended to provide information for inclusion in assessments of irrigation efficiency, and can be combined with other assessments such as energy efficiency and pump performance.

The guidelines describe procedures that ensure:

- evaluations are representative of normal operating conditions
- key in-field system performance observations are recorded
- sampling is undertaken in a way that permits extrapolation and comparison
- key performance indicators are assessed and calculated accurately and correctly
- results are reported in standard units and formats so that comparisons may be made

2.5.4 Other performance indicators

Schedule 5.1 Calculations presents guidelines for the assessment of other key performance indicators of irrigation systems and their management. These include hydraulic efficiency, pumping efficiency, and headworks efficiency.

2.5.5 List of Schedules

3	Seasonal Irrigation Efficiency
4.1	Field evaluation of Drip-Micro irrigation systems
4.2	Field evaluation of solid set irrigation systems
4.3	Field evaluation of sprayline irrigation systems
4.3	Field evaluation of sprayline irrigation systems
4.5	Field evaluation of traveller irrigation machines
4.6	Field evaluation of linear move irrigation machines
0	Field evaluation of centre pivot irrigation machines

3 Seasonal Irrigation Efficiency

Contents

3.1.1 Indicators

Schedule 3 outlines procedures for estimating measures of seasonal irrigation efficiency (SIE). A wide range of efficiency measures may be used, depending on scale, time-frame and issues under consideration. Commonly used indicators include irrigation efficiency, irrigation adequacy and drainage.

Those selected below relate to estimates of efficiency across an irrigated growing season or year. They provide information relating to economic or environmental implications of in-efficient irrigation systems or management. The indicators are calculated using soil moisture budgets; tracing inputs and outputs from a conceptual reservoir of some set size.

The schedule identifies varying levels of analysis ranging from very simplistic to highly detailed. The simplest is a quick estimate of Seasonal Irrigation Efficiency based on comparing total seasonal irrigation and rainfall with total estimated seasonal evapo-transpiration. A more detailed process is recommended where information is available. Therefore the schedule outlines a process for more detailed analysis, requiring knowledge of soil water properties, seasonal weather, potential crop water use, and irrigation system performance and management.

The quality of results from such exercises is dependent on input data, the quality of which should be recorded.

3.1.1.1 Seasonal application efficiency

Seasonal Irrigation Efficiency (SIE) is an estimate, calculated for a whole season or full year, of how much irrigation water that is applied is likely to have been used beneficially.

Beneficial uses include meeting evapo-transpiration requirements, frost protection and salinity management. In this New Zealand Code, the prime consideration is crop evapo-transpiration need, and uses for frost protection are considered separately.

The key indicator calculated is seasonal application efficiency (SAE), the ratio of crop water use to applied irrigation, net of changes in soil moisture storage.

3.1.1.2 Seasonal irrigation adequacy

Irrigation Adequacy is an estimate of whether sufficient irrigation is applied to meet the needs of a given proportion of the field. A commonly used indicator is low-quarter adequacy, which takes the average low-quarter applied depth as the scheduling criterion (Burt et al, 1997) and typically considers a single irrigation event.

Potential soil moisture deficit (PSMD) is used as the seasonal equivalent indicator, because summing individual-event irrigation adequacy results over the course of a season gives a false indication of adequacy.

Deep percolation resulting from irrigation (SDP_i), which is in effect application in-efficiency, is a key environmental indicator describing the amount of water that is lost to groundwater through non-uniformity or improper scheduling.

3.1.1.3 Other efficiency indicators

Drought induced yield loss (YL_{di}) and energy and water costs related to over-watering describe the financial implications of irrigation in-efficiencies.

3.1.2 Sources of information

Determination of irrigation efficiency indicators requires knowledge of beneficial water use, total water inputs and the soil's 'reservoir' capacity.

Typically seasonal irrigation efficiency will be calculated on the basis of the last complete season, using records of actual irrigation volumes, calculated estimates of water need, and knowledge of soil moisture storage at the beginning and end of the season.

The source of data used, and assessments of their reliability, should be recorded.

3.1.2.1 Water use

Because the key drivers of water use (PET) vary little within a district, water use by a given crop can usually be determined from district weather records and crop factors.

If on-site crop monitoring records allow, actual measured water use data should be used.

3.1.2.2 Water inputs

Water inputs require knowledge of irrigation quantities and rainfall, both adjusted to equivalent water depths. Irrigation is obviously field-specific. Because rainfall is so variable, information should relate to that received on-site.

3.1.2.3 Soil water holding capacity

Unless on-site data is known (e.g. from moisture monitoring records) soil water holding capacity (WHC) and readily available water (RAW) must be estimated.

Standard data for soils and crops in question may be available from published sources. On-site textural analysis may provide a reasonable estimate of WHC.

Plant rooting depth should be determined on-site. Text book values are widely variable and unreliable.

3.1.3 Determination of input data

3.1.3.1 Accuracy of input data and results

Many of the inputs can be entered with considerable precision, but are of limited or unknown accuracy. Therefore output results are of limited or unknown accuracy. Levels of confidence will be difficult to ascertain, but the precision of generated results should not be taken to imply a level of accuracy.

3.1.3.2 Soil moisture characteristics

The water holding potential of the soil should be calculated from the estimated soil WHC and the plant rooting depth. It is convenient to express water holding as a depth (mm).

The readily available water is estimated from WHC and some crop factor, typically management allowed depletion (MAD) or critical deficit (usually also a percentage).

For annual or new crops, root depth will increase with plant growth, so WHC and RAW will typically change over the season.

3.1.3.3 Estimating crop water requirement

Crop water requirement is dependent on climatic conditions, crop characteristics and plant available soil moisture. In a simple estimate, only the climatic and crop factors are considered.

Reference potential evapo-transpiration values (PET) should be obtained on-site or from relevant local climate station values. PET is then adjusted to account for crop specific water use factors (K_{crop}) and the ground cover fraction ($K_{ground\ cover}$). These may be combined into a single factor (K_c) the crop water use co-efficient.

The crop water requirement calculated is described as crop-adjusted evapo-transpiration (ET_{crop}) using Eqn 1.

In most cases it is satisfactory to assume plant water use stops when Critical Deficit (maximum allowable deficit, MAD) is reached. For very detailed analyses, some reduced rate of consumption should be allowed in calculating soil moisture balances.

3.1.3.4 System performance (DU_{lq})

No irrigation system applies water perfectly evenly, so under a full irrigation regime, some areas will receive more water than required while others do not receive enough.

In calculating many indicators, it is helpful to consider distribution uniformity. For example, the volume of water required to adequately meet the needs of most (7/8ths) of the crop is determined by adjusting the theoretical water requirement by the low quarter distribution uniformity coefficient (DU_{lq}).

The DU_{lq} is a key output from the system evaluations described in Schedules 4.1 through 0.

3.1.3.5 Root area wetted

Drip and micro sprinkler irrigation efficiency needs particular consideration, because only a fraction of the total soil area is actually watered.

Calculations must account for reduced soil reservoir capacity. This may be done by adjusting the effective AWC and RAW proportionally, or considering the zones separately.

3.1.3.6 Beneficial water requirements

Additional water may be required for particular purposes other than replacing ET. Alternative beneficial uses include frost protection, any leaching requirement, and pre-plant irrigations for weed germination or other reasons.

Such water use should be accounted for in determining irrigation efficiency. If water applied (e.g. for frost protection or soil conditioning) is retained and available for later plant use it should be included in calculations as irrigation.

If water applied for frost protection or soil conditioning drains (or causes other irrigation to drain) from the profile, it should be omitted from irrigation efficiency calculations, but may be included in a seasonal water use efficiency estimate (SWUE). This may include excess water applied to manage salinity (leaching), although this is rare in New Zealand.

3.1.3.7 Crop value

Financial losses can be estimated if potential yield and price are known, and a suitable drought response factor is available.

For field crops, in lieu of better data, a drought response factor, F_{dr} of 0.1% of potential yield per mm potential soil moisture deficit can be used for C4 plants (maize and sweetcorn) and a value of 0.2% /mm PSMD for other field crops.

3.1.4 Analysis detail

Decisions must be made about which factors to include and the detail with which soil moisture budgets and other calculations will be undertaken. Variables include climatic, crop and soil variables, and the irrigation system and its management.

The level of detail possible depends in part on the availability of reliable input information and in part on the purpose for which the analysis is being undertaken. The division of time periods and spatial zones for analyses also have significant effects on the results generated.

3.1.4.1 Time period

The size or number of time-steps considered influences results generated. The greater the division of any time period (the finer the time-steps) the more closely estimates can reflect reality. Wider time-steps integrate more events; summing rainfall, irrigation, ET and deep percolation. This typically underestimates certain factors such as the degree of drought and drainage.

If reliable information is available, a more detailed assessment will provide better information for future decision making. Weekly or daily weather and irrigation records provide a good or very good level of information.

3.1.4.2 Spatial variation

Analyses can be based on average values for variables such as applied depth. However, inclusion of distribution uniformity factors in calculations further increases the quality of analysis.

Typically three ‘virtual spaces’ can be considered: the area that receives the mean depth of application, and those receiving the low quarter and high quarter mean depths. Use weighted results when recombining data, using Eqn 26.

In drip or micro irrigation systems, where only part of the area is wetted, soil moisture trends in the irrigated and un-irrigated zones should also be considered separately.

Constructing independent soil moisture budgets for each area identifies where drought and drainage are occurring more accurately. The calculated indicator values can then be combined to give a value for the system as a whole.

3.1.4.3 Simple analyses

The most simple analysis uses total seasonal values to estimate an approximate efficiency. This level of analysis can be a useful starting point, easily calculated by hand or with a simple calculator.

Soil moisture storage capacity is not considered, except as change in status between the start and end of the season. Neither is consideration given to the timing of irrigation or rain, or the relationship of these events to water use (ET) in any particular time period. While this estimate can identify major problems, it does not provide the detail needed to make recommendations for improving system management.

Considerable experience in New Zealand, Australia and the United States shows that many irrigators do not have sufficient system performance knowledge, or maintain sufficient records, to allow even rough estimates to be made.

3.1.4.4 Detailed analysis

More detailed analyses involve soil moisture budgets with calculations based on periodic time steps. The desirability of computer programs to perform the calculations increases with the number of periods and detail of calculations. This level of analysis does permit increasingly accurate establishment of overall irrigation efficiency. It can be used to highlight ways in which system management, particularly scheduling and application quantities, can be adjusted to increase efficiency.

Data inputs include weather, soil moisture storage properties, crops and crop coefficients, irrigation events and system performance (distribution uniformity).

Estimates of performance rely on historic weather and management data. The quality of records of rainfall, PET and past irrigation practices determines the accuracy with which more detailed analyses of irrigation efficiency can proceed.

3.1.5 Efficiency calculations

3.1.5.1 Seasonal application efficiency

Seasonal application efficiency (SAE) is given by the ratio of water retained in the root zone to water applied to the field, over a full irrigation season or year (Eqn 8).

In more detailed calculations, the amount of water retained from each irrigation event should be summed to determine a seasonal result.

For greater accuracy, soil moisture balance calculations may be completed in each of three conceptual irrigated zones: the zone receiving the average application depth, and those receiving the average low quarter and high quarter depths.

The overall SAE is a weighted average of these calculated values, calculated according to Eqn 9.

3.1.5.2 Event Irrigation adequacy

Irrigation adequacy typically applies to an individual irrigation event. It measures the degree to which the soil moisture in some proportion of the field is restored to a level that meets or exceeds target soil water content.

A simple determinant is low quarter irrigation adequacy, IA_{lq} which is the ratio of the mean low quarter depth applied to the mean target depth required across the field as a whole (Eqn 10).

This assumes it is reasonable to adequately irrigate 7/8^{ths} of a field, leaving 1/8th under irrigated. IA_{lq} can be used to determine 'correct' irrigation scheduling:

IA_{lq}	< 1.0	under-irrigation
IA_{lq}	$= 1.0$	target irrigation
IA_{lq}	> 1.0	over-irrigation

3.1.5.3 Seasonal irrigation adequacy

If the adequacy of irrigation is summed over the course of a season, over- and under-irrigations may cancel out. This will give a false indication of adequacy, and fails to provide useful information for decision making.

For a seasonally relevant value of irrigation adequacy, potential soil moisture deficit (PSMD) gives a better indication of adequacy (lack of moisture stress). The equivalent indicator is therefore the low quarter potential soil moisture deficit ($PSMD_{lq}$). Alternatively, a PSMD for the field as a whole may be presented based on low, mean and high quarter estimates.

Seasonal deep percolation resulting from irrigation (SDP_i) is a measure of the amount of irrigation water applied that drains from the soil profile. It is therefore the equivalent indicator for excess irrigation over a season.

3.1.5.4 Potential soil moisture deficit

Potential soil moisture deficit (PSMD) is a measure of moisture stress experienced by a crop, and is correlated with yield loss.

PSMD is calculated using Eqn 3

3.1.5.5 Seasonal potential soil moisture deficit

Seasonal PSMD is calculated from soil moisture budgets by summing all deficits greater than the critical deficit (or MAD) using Eqn 12. Seasonal PSMD assumes any rain or irrigation is immediately available to plants, so is not the same as an aggregation of period SMD's.

To correspond to low quarter irrigation adequacy, a budget would be calculated using data for the low quarter zone. A potential soil moisture deficit in the low quarter zone ($PSMD_{lq}$) > 0.0mm equates to a seasonal irrigation adequacy (SIA_{lq}) < 1.0, as plants have experienced stress conditions.

To determine PSMD across the whole area, weighted values from each of the low, mean and high application zones can be summed using Eqn 26.

3.1.5.6 Seasonal deep percolation (SDP)

Seasonal deep percolation SDP includes all drainage whether from irrigation or precipitation. It is estimated from the balance of water not retained in the root zone, calculated after any surface losses have been accounted for (Eqn 13).

3.1.5.7 Seasonal irrigation deep percolation

Seasonal deep percolation resulting from irrigation (SDP_i) is a measure of the amount of irrigation water applied that drains from the soil profile. It is, in effect, seasonal application in-efficiency (Eqn 14).

$SDP_i > 0.0$ in the low quarter zone equates to seasonal irrigation adequacy > 1.0 as drainage has occurred.

To determine deep percolation across the whole area, weighted values from each of the low, mean and high application zones can be summed.

3.1.5.8 Drought induced yield loss

For most field crops, yield loss resulting from drought stress follows potential soil moisture deficit (PSMD) regardless of when in the season the stress occurs (Eqn 15).

Note: A possible exception is fruit trees and grape vines where deficit irrigation practices may be deliberately employed to control vegetative growth and or enhance crop quality without compromising yield.

3.1.5.9 Value of lost yield

The value of lost yield (cost of not irrigating correctly) is determined from the value of the crop and the amount of lost yield (Eqn 16).

Note that no account is made for loss of quality in the remaining crop using this formula.

3.1.5.10 Value of wasted water

Estimate the cost of water non-beneficially used from the amount of irrigation water lost through deep percolation, runoff and off-target application by the price paid for the water (Eqn 17).

Because SDP_i is calculated as a depth, a conversion is needed if water is charged by the cubic metre. Typically in New Zealand there is no charge on water itself, but any cost associated with its procurement, delivery or treatment may be included.

3.1.5.11 Value of wasted energy

The value of energy un-necessarily consumed is calculated from ‘wasted’ water, volumetric energy consumption and system efficiency factors using (Eqn 18). This integrates all energy losses, including those from poor headworks and mainline design.

Excess energy consumption can be reported in units of kWhr/mm/ha. Similarly, meaningful units for value of wasted energy is $/mm/ha.

3.1.5.12 Irrigation requirement

Irrigation requirement is given by crop water requirement plus any additional beneficial water requirement less received precipitation and stored soil moisture, calculated using (Eqn 19).

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4 Field evaluation of system performance

Contents

Introduction

On-site evaluation of an irrigation system utilises selected measurements to describe performance of the system, and to identify causes of poor performance and how these may be addressed. Actual measurements are used wherever possible. This ensures that the generated results describe what is happening, not what is supposed to happen.

Schedules 4.1 through 0 present guidelines for measuring irrigation system performance on-site under prevailing crop and weather conditions. Their primary focus is to determine distribution uniformity and application rates, and identify the proportional contribution key factors make to non-uniformity. A number of other key performance indicators can readily be assessed with minimal additional effort.

Additional procedures are presented in some cases. The option(s) selected by an evaluator will depend upon the purpose of the evaluation. This should always be discussed with the system owner or person requesting the evaluation be undertaken.

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4.1 Field evaluation of Drip-Micro irrigation systems

Contents

4.1.1 System description

A micro-irrigation system consists of a network of lateral pipelines fitted with low discharge emitters or sprinklers. It encompasses a number of methods or concepts; such as drip, subsurface, bubbler and micro-spray irrigation.

In a drip system, water is discharged under low pressure from emitters mounted on or built into the laterals which may lie on or above the soil surface, or be buried below the ground in the crop root zone. Such systems are distinguished by the fact that water is delivered by the system to some point, for distribution laterally (and vertically) by the soil medium. Discharge rates are generally less than 8 L/h for point-source emitters and 12 L/h per metre for line-source emitters.

Micro-sprayer (micro-jet) and mini-sprinkler systems rely on aerial spread of water droplets to achieve significant lateral displacement before water enters the soil. There may be further lateral spread within the soil itself. Discharge rates are typically less than 60 L/h.

Micro-irrigation systems are potentially a very efficient way to irrigate. Water can be applied precisely to the point where it is required for crop growth, and not to inter-row or other non-beneficial areas. The system is virtually unaffected by wind or surface evaporation. Because of the very low labour requirement per irrigation, such systems allow frequent light irrigations as needed to best fit crop water requirements and optimise production.

4.1.1.1 This Schedule

This schedule was developed to provide guidelines for irrigators and others undertaking evaluations of such systems as a ‘snapshot exercise’ under prevailing field conditions.

It outlines procedures to be followed when assessing distribution uniformity of irrigation systems applying water through point-source or line-source emitters, micro-sprayers, or mini-sprinklers, where each plant is watered by one or more outlets.

The guidelines presented in this schedule are not intended for evaluations of sprinkler systems where one sprinkler serves more than one plant [See 4.2 Field evaluation of solid set irrigation systems or 4.3 Field evaluation of sprayline irrigation systems] except where that one sprinkler serves two plants equally.

4.1.2 Special features for analysis

4.1.2.1 Environmental factors

Wind conditions at the time of the test will not normally influence results from this test. The tests assume all water from an emitter, sprayer or sprinkler is allocated to a single tree (or halved between two trees) the influence of wind is negligible.

Testing is carried out over a very short time-frame, so evaporation will have no significant effect on evaluation results.

4.1.2.2 Soil moisture

The behaviour of water in the drip wetted zone is influenced by conditions existing in the soil at the time, and by previous irrigation practices. Examine the wetted zone under a number of representative emitters before the system is started, and record dimensions and approximate moisture content (see Fig. 4.1.2).

4.1.2.3 Distribution Uniformity

Overall field distribution uniformity of a micro-irrigation system is determined by system pressure variation and variation in emitter performance. In a brand new well designed system, overall system performance is determined by accepted pressure variation within the lateral network, emitter performance characteristics and variation in manufacture.

In older systems, these influences are compounded by damage to and deterioration of components, and by physical blockages of very small orifices. The nature of the system, with low pressures and very small orifices, requires that water quality be high.

4.1.2.4 Permanent set system

Because drip irrigation systems are typically set, each plant receives water from the same emitter(s) at every irrigation. Non-uniformity is repeated so there is an increased demand for high uniformity. There is no 'smoothing' effect as with moving systems, where non-uniformities vary between events and tend to cancel.

4.1.2.5 Multiple outlets per plant

In many cases individual plants are served by more than one emitter. Even small drip-irrigated row-crop plants can be considered to have multiple emitters if the wetted area per emitter is such that, if every other emitter was blocked, each plant would still receive (some) water.

4.1.2.6 Small root fraction wetted

Many drip-micro systems installed on permanent crops in New Zealand wet only a fraction of the available root area. Because most areas in New Zealand receive significant rain throughout the year, root systems generally cover the entire field.

4.1.2.7 Low operating pressures

Micro-irrigation systems usually operate at low pressures. This means a small actual pressure variation is large in relative terms, and can have a significant effect on flow variation. Typical pressures range between 200 – 400 kPa (30 – 60 psi) depending on system size and terrain undulation.

The emitters themselves usually operate in the range 35 – 170 kPa (5 – 25 psi).

4.1.2.8 Low discharge flows

Discharge rates for point-source emitters are generally less than 8 L/h and for line-source emitters less than 12L/h per metre. Micro-sprinklers have higher flow rates, typically under 175 L/h.

4.1.2.9 Field variability

The performance of drip irrigation systems may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, lateral pipe lengths, and variable distances from headworks to lateral pipe inlets.

4.1.2.10 Field elevation

If the field is level, the hydraulically closest and furthest points for the headworks will normally have the highest and lowest inlet pressures respectively. These will be sampled as part of the basic testing procedure.

If field elevation varies significantly, consider increasing the number of tests to increase accuracy of distribution uniformity assessments. Record the (relative) elevations of each test site, and draw a profile sketch along a typical lateral if necessary.

4.1.2.11 Differences between drip and microsprinkler systems

The drip system discharges water directly to a point relying on the soil matrix to redistribute water within the root zone, whereas the microsprinkler discharges water through the air resulting in an immediate increase in area covered. This can mean that a smaller root volume is irrigated by drip systems.

Drip systems may have relatively long operation times, compared to micro-sprinklers which typically have higher flow rates (<175 L/h) and require shorter irrigation durations.

Because the area wetted by a drip system is typically less, the depth of watering for a given volume is greater, and care must be taken to avoid deep drainage losses.

4.1.3 Technical materials

4.1.3.1 Relevant standards

The schedule has been developed with reference to international standards and published practices. In the case of drip-micro there is (at June 2005) no accepted international standard for on-site evaluation of system performance. This schedule considers laboratory testing procedures and procedures described by the Irrigation Training and Research Center. Procedures determined are practical for implementation in a cost effective on-site evaluation.

ISO 9261:1991 Agricultural irrigation equipment – Emitting pipe systems – Specification and test methods [Laboratory testing of new manufactured drip-line]

ASAE EP405.1:2001 Design and installation of microirrigation systems

ASAE EP 458: 1995 Field evaluation of microirrigation systems (Withdrawn)

ITRC Irrigation Evaluation: Drip micro 2000 [de facto standard in California].

4.1.3.2 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)

Burt, C.M. and S.W. Styles. 1994. *Drip and Microirrigation for trees, vines and row crops (with special sections on buried drip)* Irrigation Training and Research Center (ITRC), California Polytechnic State University, San Luis Obispo, CA. 261pp

Smajstrla, A.G., B.J. Boman, D.Z.Haman, D.J.Pitts, and F.S.Zazueta. 1998. *Field evaluation of microirrigation water application uniformity.* Bulletin 265, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

4.1.3.3 Abbreviations

Reference abbreviations used in text

Cal	Burt, Walker, Styles and Parrish. 2000
DAM	Burt, C.M. and S.W. Styles. 1994.
NZI	Anon. 2001.
UFL	Smajstrla, A.G., et al. 1998.

4.1.3.4 Related schedules and appendices

3	Seasonal Irrigation Efficiency
4.2	Field evaluation of solid set irrigation systems
5.4	Reporting format

4.1.4 Test procedures

This schedule outlines procedures to be followed when assessing distribution uniformity of a micro-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 same system, or when benchmarking against other systems.

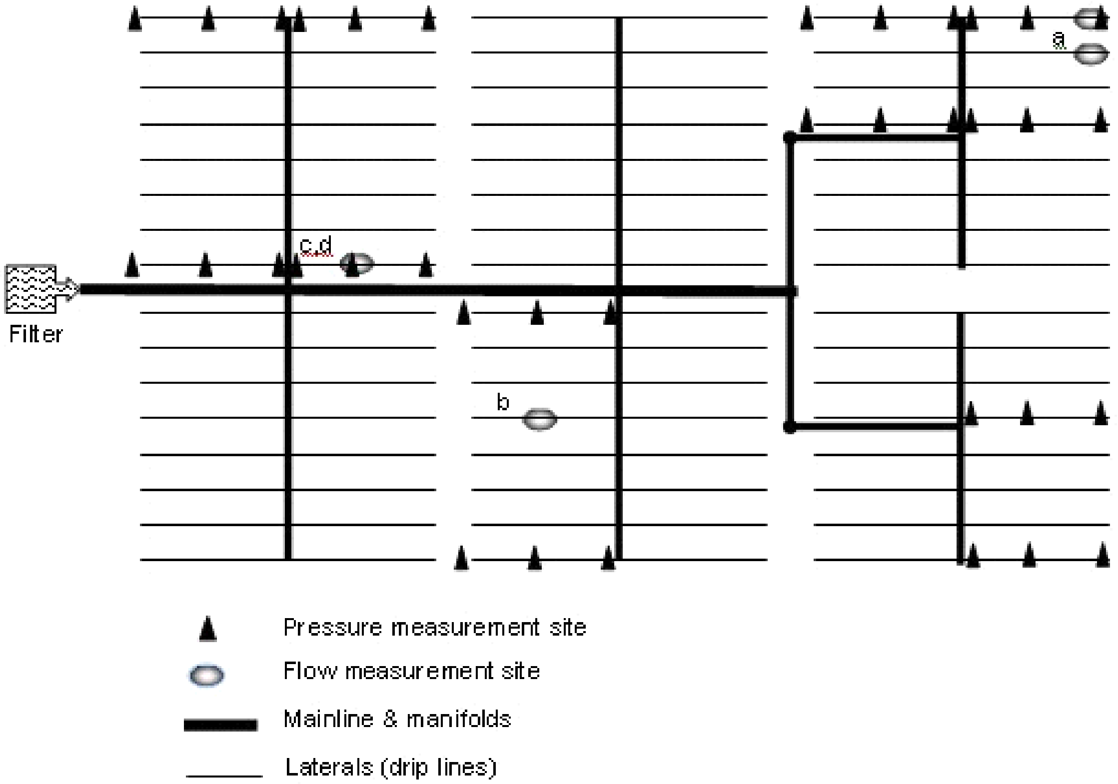

Fig. 4.1.1 Drip-micro irrigation system showing location of pressure and flow measurement sites

4.1.5 Test site

Specific locations are selected (Fig. 4.1.1) to allow an overall field uniformity to be calculated.

Emitter flow tests should be undertaken in three areas representing the cleanest, average and dirtiest parts of the system.

Pressure sampling is undertaken at defined points in as many blocks as practical.

4.1.6 System survey

4.1.6.1 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).

4.1.6.2 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 lateral with the results unless the ground surface is level.

4.1.7 System operation

4.1.7.1 Emitter package

Before testing the system, verify that the emitters have been installed according to the design specifications, unless specified otherwise by the client (ISO).

4.1.7.2 System pressure

The test 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).

Small pressure differences are proportionally large in systems operating at low pressures. To maintain constant pressure, ensure the system is not affected by other significant system draw-offs such as other irrigation machines or dairy sheds.

One test (4.1.13.7 Adjusted pressure test) requires that the system pressure be changed to allow determination of emitter coefficients. Ensure the system is stable at the new pressure before commencing and throughout this test also.

4.1.7.3 Water quality

The water used for the test should be the same as that normally used for irrigation. Water quality is of paramount importance for drip irrigation systems and is the subject of certain evaluations in the procedures that follow.

For personal health and safety reasons, particular caution is necessary if water has been treated for any purpose, such as with acid or biocides, or contains effluent or other potential bio-hazards.

4.1.7.4 Water temperature

The water used for the test should be the same as that normally used for irrigation. Water temperature in exposed black plastic lateral can increase markedly under intense sunlight. Note the water temperature at each test site.

4.1.7.5 Injection devices

If the system is designed with an injection device that is normally operative, perform the test with the injection device operating. Otherwise ensure it is not operational for the duration of testing.

4.1.8 Environmental measurements

Wind effects and evaporation impacts on collected volumes are likely to be insignificant with drip-micro systems. Measure and record if conditions suggest effects are possible.

Measure topographical variation if the field is not level. Ensure pressure measurements include lowest and highest blocks / areas.

4.1.9 Field observations

4.1.9.1 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.

4.1.9.2 Crop appearance

Observe the crop for signs of stress or growth difference.

Check for plants receiving little or no water because of system faults or blockages.

Measure or estimate the crop ground cover proportion.

4.1.9.3 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.

4.1.9.4 Soil properties

Determine the soil texture and depth of rooting.

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

4.1.9.5 Emitter spacing

For each block determine the emitter spacing and the number of emitters per plant. The minimum number will be one (1.00), but may not be a whole number. If necessary, calculate the average number of emitters by counting along a number of plants.

4.1.9.6 Soil wetted volume

Assess the spread and depth of wetness under a number of drippers across the block and record.

Key dimensions include the surface wetted diameter, the wetted diameter at the widest point, the wetted diameter at about 30cm and the depth in relation to plant root zone (**Fig. 4.1.2**).

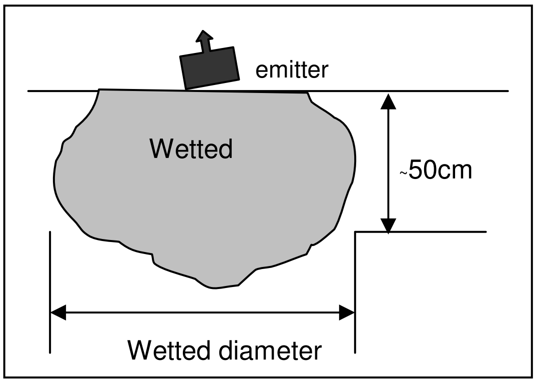

Fig. 4.1.2: Soil wetted volume

4.1.10 System checks

4.1.10.1 Sprinkler/emitter package

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

4.1.10.2 Filtration

In microirrigation systems there may be a number of in-line filters at off-takes and/or laterals in addition to the main headworks filters. Identify the type(s) of filter fitted.

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

Identify when filters were last checked or cleaned and the frequency of flushing.

4.1.10.3 Lateral contamination

Randomly select at least three laterals in the block furthest from the filter. Inspect them for contaminants by flushing the lowest most distant ends through a nylon filter (sock) (Cal).

Record the time required for the water to run clear.

Rate the amount of material (sand, clay, bacteria/algae, other) caught in the nylon sock using scale:

1 = none 2 = slight 3 = medium 4 = major

4.1.10.4 Emitter blockages

Conduct a visual check to determine that emitters are operating correctly. Replace obvious failures before the test.

Determine and record the cause of blockage in any emitters that are non operational.

Remove five emitters from distant hose ends and rate the material (sand, precipitates, bacteria/algae, insects, plastic parts, other) causing plugging using the scale:

1 = none 2 = slight 3 = medium 4 = major

Note: This may require destruction, so ensure spares are available (Cal).

4.1.10.5 System leakages

Conduct an overall visual check (as possible) of headworks, mainline and the system to identify any leakages or other losses. Estimate percentage loss.

4.1.10.6 Pressure regulators

Identify locations of pressure regulators in the system, including automatic pressure control valves, manifold or off-take pressure regulators and pressure regulators on individual hoses.

Identify any other points where pressure adjustments have been made, noting any presence of regulation valves in series.

4.1.10.7 Unequal drainage

Observe the flow duration from emitters after the system is turned off.

Determine the length of time some emitters continue to run after most have stopped.

Assess the percentage of emitters that do this (Cal).

4.1.11 Flow measurement

4.1.11.1 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 (this may take up to 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.

4.1.11.2 Energy use

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

4.1.12 System pressure

Equipment specifications (see: 5.3.2 Pressure gauges).

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

2. Mainline pressures

Measure pressure at each off-take

3. Distribution network pressures

Pressure variation at emitters is one of the key factors influencing uniformity of a drip system.

Under this evaluation process, all pressure measurements are made using a pitot tube inserted into laterals (see: 5.3.2 Pressure gauges).

A number of measurements are required to assess variation in pressures after different pressure regulators (or off-takes), between laterals downstream of a pressure regulation point (on a manifold) and along the length of the laterals. The locations of pressure test points are therefore selected accordingly (Cal).

4.1.12.1 Pressure regulator variation

Variation in pressure regulator performance resulting from manufacturing variation, settings or design, is determined by selecting a minimum of three blocks. These should represent the highest, intermediate and lowest pressures. Typically they will be at the off-takes hydraulically closest, in the middle and furthest respectively from the headworks (see Fig. 4.1.1).

In greatly undulating fields, the blocks with the highest, intermediate and lowest elevations may represent the greatest variation. In this case, and in very large blocks, assess these as well, giving a minimum of six blocks measured.

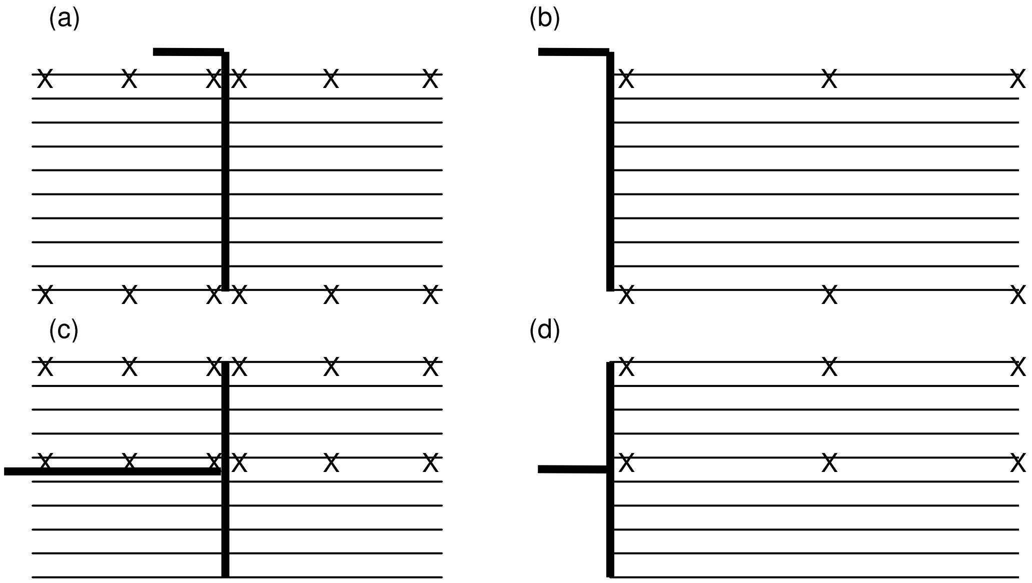

Fig. 4.1.3: Points for pressure testing

4.1.12.2 Manifold pressure variation

Variation in pressure reaching the inlet of individual laterals is determined by measuring the inlet pressure at both the first lateral after the pressure regulation point and the last lateral on the manifold, *in each assessed block* (see Fig. 4.1.3 a-d).

A total at least three blocks will be measured depending on system size and topography.

If the manifold is at one end of the block with laterals flowing in one direction only, it is treated as one block (see Fig. 4.1.3 b, d).

If paired laterals flow in both directions away from the manifold, the two sides are treated as separate blocks (see Fig. 4.1.3 a & c). Pressure readings may be taken on each side, counting as two separate blocks, in which case at least six individual blocks should be assessed.

4.1.12.3 Lateral pressure variation

Variation in pressure along the lateral is assessed by taking pressure measurements *along representative laterals.* Three pressure measurements are taken from each of two laterals at the end, the middle, and the inlet (see Fig. 4.1.3 a-d).

4.1.12.4 Station pressure variation

The variation in pressure across the entire station is determined from the above measurements. On small simple systems, a minimum total of 18 measurements will be used, comprised of six measurements from each of three blocks.

On larger or undulating systems, 36 or more pressure measurements will be used (six measurements from six or more blocks). Increasing the number of measurements will improve the quality of the results.

4.1.12.5 Lateral filter pressure loss

In-line filters or strainers fitted at the beginning of laterals can be the source of pressure variation either by inherent design or through becoming blocked.

If such filters are fitted, randomly sample five filters from the ‘dirtiest’ block.

Record the pressure in each lateral with the filter in, then remove the filter element and record pressure with it out. Calculate pressure loss as the average of the five readings.

4.1.13 Emitter performance

4.1.13.1 Emitter flow measurement

The purpose of these tests is to determine the variation in flow and the relative causes. These include emitter variation (whether the result of manufacturing variability, in-field damage or blockages) as well as pressure variation in the system (~Cal).

Emitter flows are measured at three different locations representing the ‘cleanest’, ‘average’ and ‘dirtiest’ areas within the station. The selected locations each have a different probability of emitter clogging. (Fig. 4.1.1 a-c)

If the emitter ‘pressure-flow coefficient’ must be determined (manufacturer’s data is not available or is queried) the ‘cleanest’ test is repeated with the system pressure adjusted by 20%.

4.1.13.2 Flow collection

Flow from individual emitters can be collected in any container. Ensure all discharge is collected including any from leaks around the emitter, and any water that ‘dribbles’ along the lateral tubing. Split rubber rings placed either side of the emitter help avoid such dribbles.

Drip tape systems with many closely spaced inbuilt emitters may be measured by collecting all discharge from a known length of lateral. Useful lengths are either 1.0 or 0.5 metres, in which case a corresponding length of spouting, or PVC pipe cut in half lengthways, is convenient (see: 5.3.1 Collectors: Design, dimensions and orientation).

The minimum collection time should be five minutes or such time as is necessary to collect at least 250 mL. Measure volumes promptly especially in hot weather.

4.1.13.3 Collector placement

Check that lateral pressure within each test location (block) varies by no more than about 7 kPa. If necessary split the test across two adjacent laterals.

Note that measurement locations avoid inlet ends of laterals as pressure variation in the first 40% is typically too great.

To avoid pressure effects on flows, *all emitters in each measurement location (block) must be at the same pressure*. The pressure in *different* measurement locations (blocks) need not be the same.

4.1.13.4 Dirtiest area uniformity test

Usually the dirtiest location (that most likely to have clogging) is the one hydraulically furthest from the headworks and filters (Fig. 4.1.1 (a)). Often this is also a lower area. If a different area is known to be dirtiest, select that area instead.

Select twenty eight (28) adjacent emitters (or dripline sections) at the end of the lateral at the end of the manifold. If necessary use adjacent laterals to remain within pressure variation limits.

A larger sample set is used for this test to account for the greater variability that can be anticipated.

4.1.13.5 Average area uniformity test

This test should be conducted in an area typical of average conditions for the system. It is likely to be somewhere in the middle of the station, neither close to nor very far from the headworks and filters (Fig. 4.1.1 (b)).

Select sixteen (16) adjacent emitters (or dripline sections) near the middle of a lateral near the middle of the manifold.

For this and the 'clean area' tests, a sample size of 16 is sufficient assuming the system is clean and emitter variability is low.

4.1.13.6 Cleanest area uniformity test

Usually the cleanest location (that least likely to have clogging) is the one hydraulically nearest to the headworks and filters (Fig. 4.1.1 (c)). This provides information about the extent and effects of emitter variation on uniformity. If a different area is known to be cleanest, select that area instead.

Select sixteen (16) adjacent emitters (or dripline sections) near the middle of the lateral closest to the off-take. Avoid the inlet end as pressure variation will be too great.

4.1.13.7 Adjusted pressure test

The effect of pressure change on emitter flow is calculated using the discharge coefficient. If a manufacturer's value is unavailable, or is queried, the discharge coefficient can be determined from measurements of the same emitters at different operating pressures (Fig. 4.1.1 (d)).

Repeat the cleanest area uniformity test after adjusting the lateral pressure by about 20%.

If the normal pressure is 50 – 80 kPa try to increase pressure, if necessary by closing down some sections of the station. If normal pressure is 100 – 140 kPa reduce pressure.

After this test, reset the system to its normal operating conditions.

4.1.14 Optional tests

If desired, repeat tests may be run to determine distribution uniformity under different conditions, such as pressure, or in different locations.

4.1.15 Performance indicators

4.1.15.1 Distribution uniformity (DU_{lq})

A determination of 'Field DU_{lq}' 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.

4.1.15.2 Emission uniformity (EU)

The purpose of uniformity determination is to firstly assess the evenness with which individual plants receive water, and secondly to identify those factors causing non-uniformity.

The procedure established below estimates an overall Field Emission Uniformity, and estimates the relative contributions to non-uniformity made by pressure, emitter manufacture, wear and tear, drainage and uneven spacing.

The use of statistical uniformity assessments enables the different contributing factors to be separated out. The determinations will be imperfect but sufficiently accurate to identify areas where management can make changes to improve system performance.

In drip systems the coefficient often quoted is the emission uniformity coefficient (EU), which corresponds mathematically to the Christiansen coefficient used in sprinkler irrigation uniformity assessments.

EU strictly applies only to variation along a single lateral, which is not representative of a field as a whole. However, here a low quarter emission uniformity EU_{lq} is adopted to describe overall field performance.

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

4.1.15.3 Emission v's Distribution Uniformity

Statistically derived emission uniformity (EU_{stat}) can be related to low quarter distribution uniformity (DU_{lq}), here presented as EU_{lq}, assuming a statistically normal distribution. The relationship is given by equation Eqn 36 Emission v's Distribution Uniformity.

Acceptability classifications for whole field uniformity determinations for each measure are presented in Table 4.1.1 (based on ASAE EP458).

Table 4.1.1 Acceptability of Whole Field Determinations of Uniformity

Rating	Emission uniformity (EU_{stat})	Distribution uniformity (DU_{lq})
Excellent	> 0.95	> 0.94
Very Good	0.94 – 0.90	0.93 – 0.87
Good	0.89 – 0.80	0.86 – 0.75
Fair	0.79 – 0.70	0.74 – 0.62
Poor	0.69 – 0.60	0.61 – 0.50
Unacceptable	< 0.60	< 0.50

4.1.15.4 Application rate

Application rates under drip-micro irrigation are not generally considered in evaluations. They are complicated by the volume being applied at a point of very small area.

In drip systems some ponding is expected and assists horizontal displacement of water. In micro-jet or mini-sprinkler systems some ponding is often present.

4.1.15.5 Applied depth

In drip-micro irrigation, the volume applied must be adjusted for the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption (mm/day). Under micro-irrigation, not all the area available for plants is wetted.

4.1.15.6 Infiltration depth

The volume applied per irrigation is delivered to a fraction of the area available. The infiltration depth estimates the depth to which the wetting front will progress under the emitter. Compare infiltration depth to the root zone depth to determine whether excess irrigation is applied.

4.1.16 System uniformity

4.1.16.1 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 uniformity' requires that adjustments are made to account for various factors, including multiple outlets serving individual plants and unequal system drainage.

Adjustments are not generally required to account for evaporative losses from collectors as collection times are short and measurement should be rapid.

If the station contains areas with different emitters, flows or spacings, these areas need to be assessed individually. The Irrig8 program allows up to three areas with different plant or systems spacing to be analysed.

4.1.16.2 Field emission uniformity, FEU_{lq}

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

Overall uniformity incorporates the effects of pressure variation, emitter variation, and the smoothing effect of multiple emitters supplying individual plants.

In addition, it is adjusted for emitter defects (wear and plugging), unequal drainage after system shut-down and may be further adjusted to account for different plant or emitter spacings within the field.

$$FEU_{lq} = \left[1 - \sqrt{(1 - PEU_{lq})^2 + (1 - EEU_{lq})^2 + (1 - F_{drainage})^2 + (1 - F_{spacing})^2} \right]$$

Where:

FEU_{lq}	is low quarter field emission uniformity
PEU_{lq}	is low quarter pressure emission uniformity
EEU_{lq}	is low quarter emitter variation factor
$F_{drainage}$	is the uneven drainage factor
$F_{spacing}$	is the uneven plant spacing factor

4.1.16.3 Pressure emission uniformity (PEU_{lq})

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

Pressure emission uniformity (PEU_{lq}) is calculated from derived flows, using the low quarter uniformity formula.

4.1.16.4 Pressure derived flows

Pressure derived flows are calculated for each of the pressure measurements taken across the field (see 4.1.12 3 Distribution network pressures) 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.

4.1.16.5 Emitter emission uniformity (EEU_{lq})

Determine an emitter emission uniformity coefficient to account for manufacturing variation, wear and tear and blockages, and the number of emitters per plant.

Emitter variation is calculated from emitter manufacturing coefficient of variation, CV_{man} and the mean emitter defect coefficient of variation, CV_{defect} determined from emitter performance tests 1, 3 and 4, (see 4.1.13 Emitter performance). The statistical distribution parameter for a normal distribution, K_{lq}=1.27 is used to convert to a DU_{lq} form.

Determine the emitter variation factor, EEU_{lq} using Eqn 37.

4.1.16.6 Uneven drainage coefficient ($F_{drainage}$)

The uneven drainage coefficient is an estimate the impact of water draining from the system such that some plants receive greater amounts of irrigation than others. When short run times are used on undulating ground this can have a significant effect on overall system uniformity.

Calculate the uneven drainage coefficient using Eqn 38.

4.1.16.7 Uneven spacing coefficient ($F_{spacing}$)

The uneven spacing coefficient is an estimate of non-uniformity caused by unequal plant or emitter spacings in different zones within the main field. In general a full canopy planting should require a similar <u>depth</u> of water (but not volume per plant) regardless of the distance between plants, emitter spacing or emitter discharge rates.

Calculate the uneven spacing coefficient using Eqn 39.

4.1.17 Other uniformity factors

4.1.17.1 Pressure adjusted emitter flow

Determine pressure adjusted flows for each emitter measured in the emitter performance tests (see clean, middle and dirty area tests 4.1.13 Emitter performance).

Adjust the flow of each emitter to an equivalent flow at mean field pressure using Eqn 40.

4.1.17.2 Estimating Cv_{man}

In the absence of data from manufacturers or a testing facility, an estimated value of manufacturing variance can be calculated using data collected from the clean location emitter flow tests [see 4.1.13.6 Cleanest area uniformity test].

Calculations should follow the procedure set out in Eqn 20.

Table 4.1.2. Acceptable values for brand new emitter manufacture quality Cv_{man}

Classification	Manufacturing Coefficient of Variation (Cv_{man})	
	Burt & Styles	CATI (UFL)
Excellent	< 0.03	<0.05
Average	0.03 – 0.07	0.05 – 0.10
Marginal	0.07 – 0.10	0.10 – 0.15
Very Poor	> 0.10	>0.15

Adopted from Burt and Styles 1994 and Pitts (UFL)

4.1.17.3 Emitter defect coefficient of variation (Cv_{defect})

The emitter defect coefficient of variation quantifies the contribution to non-uniformity resulting from broken, worn or blocked emitters.

It is estimated as the difference between the coefficient of manufacturing variation (Cv_{man}) and the coefficient of pressure adjusted flow variation Cv_{Qpadj} in each test block 1,3 & 4 (4.1.13 Emitter performance).

Calculate Cv_{defect} using Eqn 41.

Note that Cv_{man} may have been determined in the field from the “cleanest area” flow test measurements. It is not possible to assess the individual contributions of emitter variation any more than as established above.

4.1.17.4 Sources of pressure variation

Non-uniformity arises from pressure variation in three identifiable places: variation between blocks, along manifolds, and along laterals.

Estimates of the relative contributions are made by calculating the maximum pressure variation (kPa) between laterals, and the maximum pressure variation along laterals. These should be expressed as a percentage of the total pressure variation.

4.1.17.5 Design Uniformity (EU_{des})

The design uniformity coefficient is an estimate of brand-new system uniformity determined from manufacturer’s emission uniformity (EU_{man}), the number of emitters per plant, and accepted design pressure variation.

Design uniformity (EU_{design}) should be reported as a decimal, calculated using Eqn 42.

The equation utilises only mean low quarter and mean pressure values, so is not strictly a statistical measure.

4.1.18 Application calculations

4.1.18.1 Equivalent applied depth (Dz_{app})

In drip-micro irrigation, the volume applied must be adjusted for the area served to ensure that the depth of irrigation water applied is comparable with PET and water consumption (mm/day). Under micro-irrigation, not all the area available for plants is wetted.

The equivalent applied depth is calculated from emitter flow and number, irrigation duration and ground area per plant using Eqn 45.

4.1.18.2 Infiltration depth

Infiltration depth under drip-micro irrigation is calculated from applied volumes and the wetted area per emitter (Fig. 4.1.2) using Eqn 44 .

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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

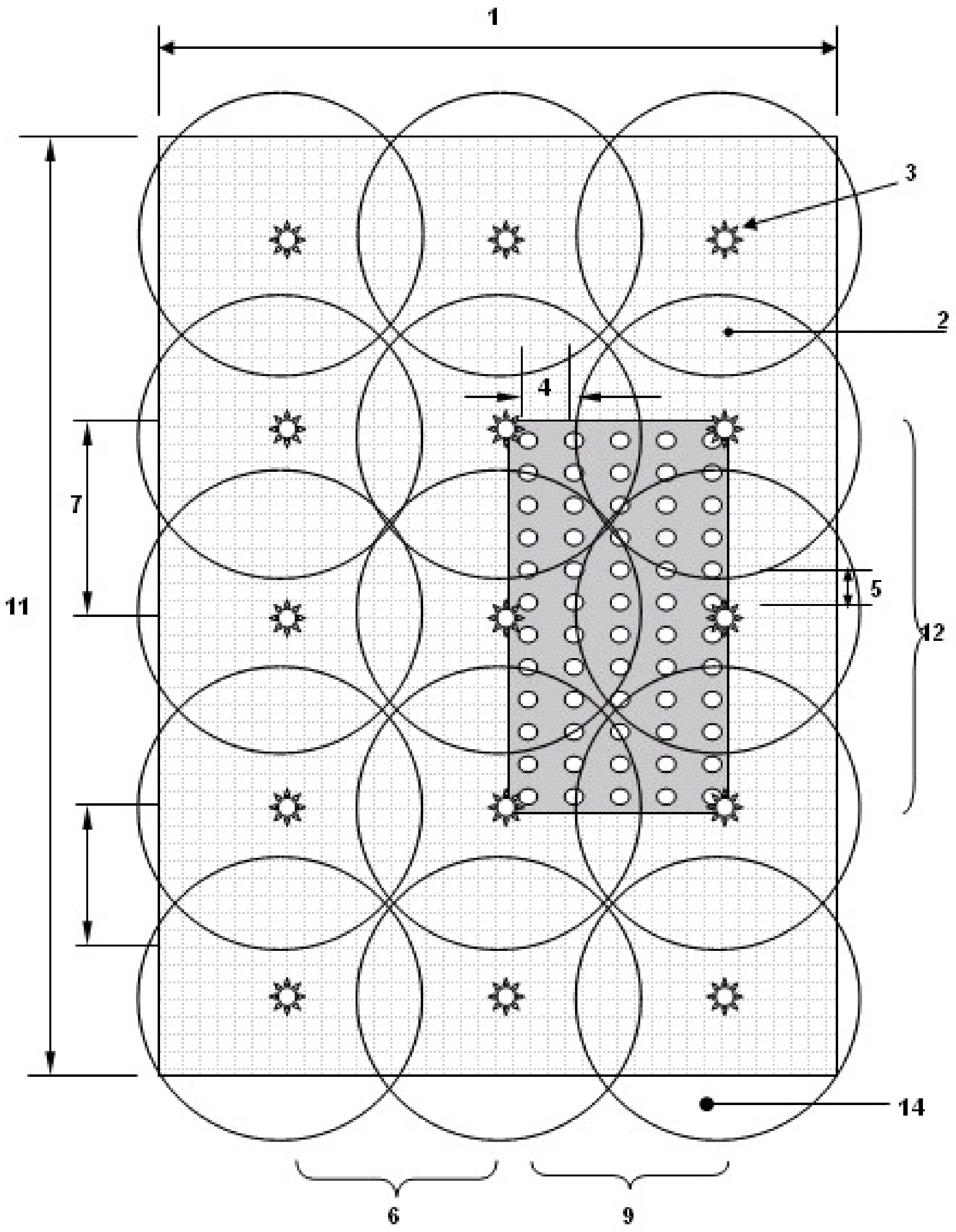
4.2.3.4 Related schedules and appendices

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

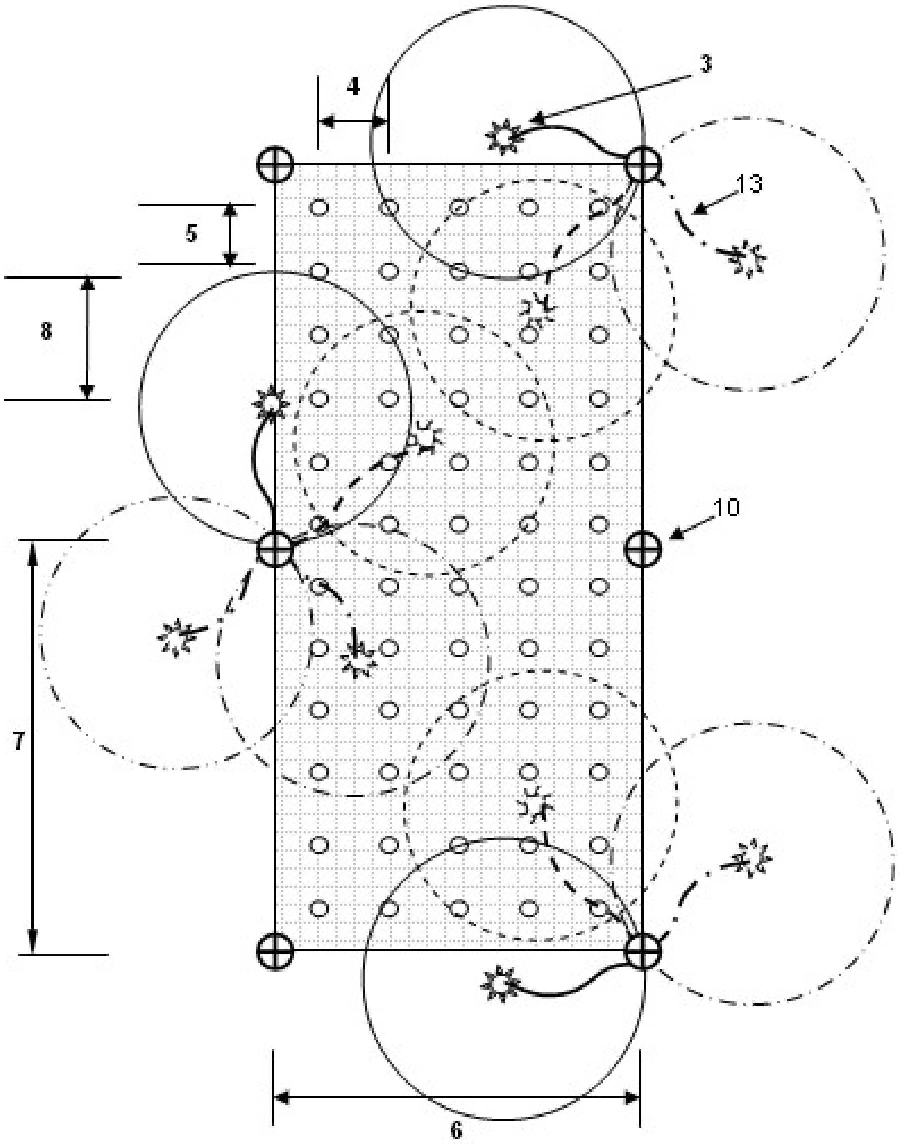
This schedule outlines procedures to be followed when assessing distribution uniformity of a solid set irrigation system as a 'snapshot exercise' under prevailing field conditions. To gain most benefit, conditions at the time of the test should be representative of those experienced in normal operation.

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
2	Irrigated area A_i
3	Sprinkler
4	Collector row (transverse) spacing, s_{cr}
5	Collector column spacing, s_{cc}
6	Sprinkler row spacing D_{sr}
7	Sprinkler column spacing D_{sc}
8	Sprinkler wetted radius, rw
9	Extent of collector rows
11	Irrigated area length, L_t
12	Extent of collector columns
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.

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

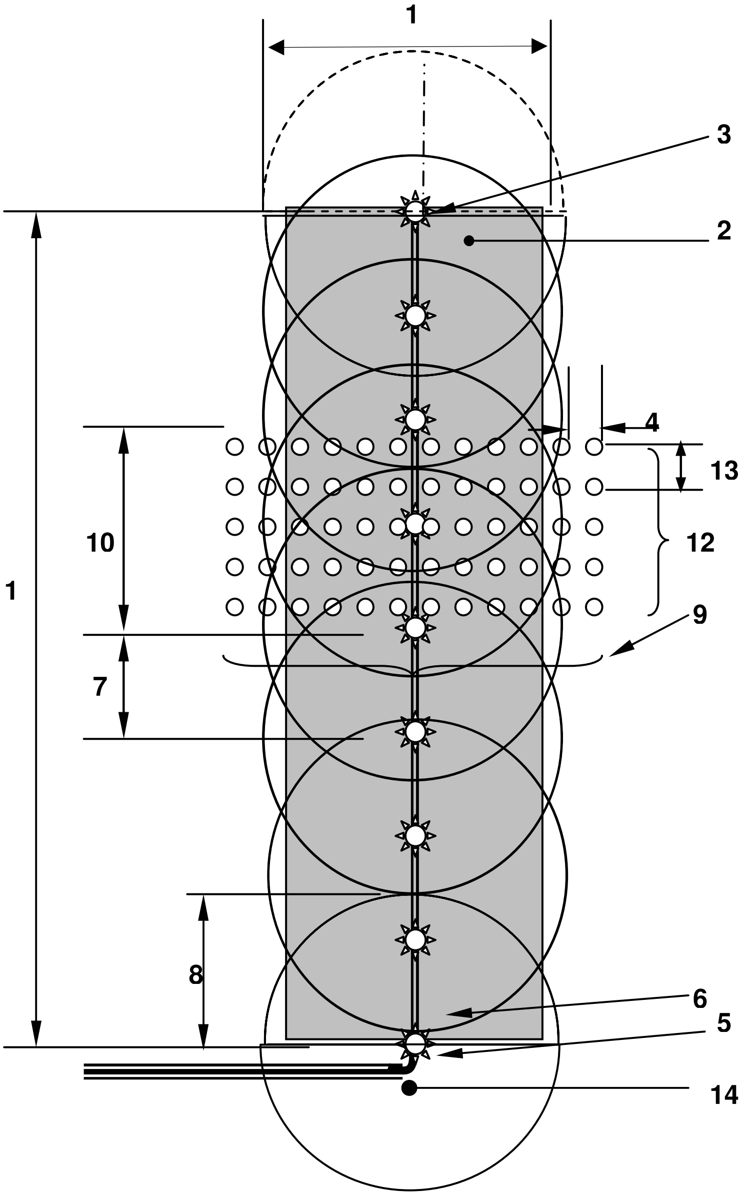
4.3.3.4 Related schedules and appendices

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
2	Irrigation strip accounting for overlap
3	Sprayline: final sprinkler
4	collector row (transverse) spacing, s_{cr}
5	Hydrant or end of mainline
6	Sprayline: initial sprinkler
7	sprinkler spacing D_s
8	sprinkler wetted radius, r_w
9	extent of collector rows
10	transverse line layout zone (= 2 D_s)
11	length of strip, sprayline length, Lt
12	extent of collector columns
13	collector column (longitudinal) spacing, s_{cc}
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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4.4 Field evaluation of multiple sprayline irrigation systems

Contents

4.4.1 System description

Multiple sprayline irrigation systems are characterised by movable laterals with sprinklers at fixed intervals. The system is usually arranged so that successive shifts create a grid pattern of sprinkler positions. The spacing between sprinklers may vary considerably. The sprinkler layout pattern that is achieved in practice may be either square, triangular or somewhere in between.

Multiple sprayline systems typically have smaller sized impact sprinklers. The laterals are connected to permanently buried mainlines and hydrants by a long polythene pipe. Each lateral is moved manually around 6- 14 positions.

4.4.2 Special features for analysis

4.4.2.1 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.

4.4.2.2 Semi-permanent set system

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

Because the laterals may be returned to similar positions, any inherent non-uniformity (e.g. not the result of wind) can be 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.

4.4.2.3 Lateral friction

Headloss in lateral lines is a potential cause of flow and distribution pattern variability. Sprinklers used are not normally pressure compensating.

4.4.2.4 Field variability

The performance of irrigation systems may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, lateral pipe lengths, and variable distances from headworks to lateral pipe inlets.

Systems set out in varying topography are subject to pressure effects. In addition, systems that cover large areas may have pressure differences resulting from mainline and sub-main friction losses.

The assessor and client should discuss what testing is desired and the conditions under which any tests should be conducted.

4.4.2.5 Field elevation

If the field is level, the hydraulically closest and furthest points for the headworks will normally have the highest and lowest inlet pressures respectively. These will be sampled as part of the basic testing procedure.

If field elevation varies significantly, consider increasing the number of tests to increase accuracy of distribution uniformity assessments. Record the (relative) elevations of each test site, and draw a profile sketch along a typical lateral if necessary.

4.4.3 Technical materials

4.4.3.1 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*

4.4.3.2 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)

4.4.3.3 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

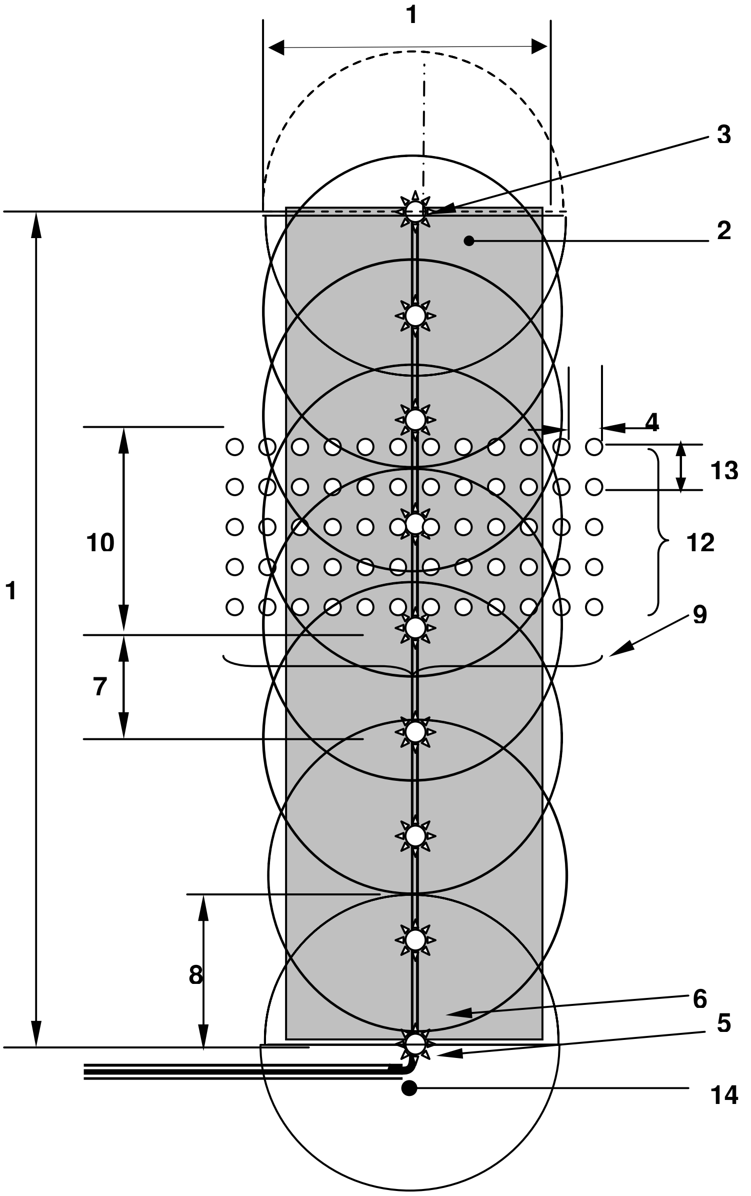
4.4.3.4 Related schedules and appendices

Section 2:	Conducting a field evaluation
Schedule 3	Seasonal irrigation efficiency assessment
Schedule 4.1	Field evaluation of Drip-Micro irrigation systems
Schedule 4.3	Field evaluation of sprayline irrigation systems
Appendix 5.2.2	Evaporation from collectors
Appendix 5.4	Reporting format

4.4.4 Test procedures

This schedule outlines procedures to be followed when assessing distribution uniformity of multiple lateral 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 4.4.1: Field collector layout for multiple lateral sprayline systems

4.4.5 Test site

4.4.5.1 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.

4.4.5.2 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.

4.4.6 System survey

4.4.6.1 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 5.3.5 **Measurement of sprinkler pressure**).

4.4.6.2 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.

4.4.7 System operation

4.4.7.1 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.

4.4.7.2 Sprinkler package – multiple lateral sprayline 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.

4.4.7.3 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.
- An alternative pressure flow test is required to determine the pressure flow relationship.

4.4.7.4 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 multiple lateral sprayline 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.

4.4.8 Environmental measurements

4.4.8.1 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).

4.4.8.2 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 .

4.4.8.3 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.

4.4.9 Field observations

4.4.9.1 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.

4.4.9.2 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.

4.4.9.3 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.

4.4.9.4 Soil properties

Determine the soil texture and depth of rooting.

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

4.4.9.5 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.

4.4.9.6 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.

4.4.10 System checks

4.4.10.1 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

4.4.10.2 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.

4.4.10.3 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).

4.4.11 Flow measurement

4.4.11.1 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.

4.4.11.2 Energy use

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

4.4.12 System pressure

Equipment specifications (see: 5.3.2 Pressure gauges).

4.4.12.1 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

4.4.12.2 Distribution network pressures

Pressure variation at sprinklers is one of the key factors influencing uniformity of a multiple lateral system.

Under this evaluation process, pressure measurements are made using a pitot tube inserted into laterals if soft walled (see: 5.3.2 Pressure gauges) or inserted into the stream at the nozzle outlet (see Pressure gauges).

A number of measurements are required to assess variation in pressures after different pressure regulators (or off-takes), between laterals downstream of a pressure regulation point (on a manifold if present) and along the length of the laterals. The locations of pressure test points are therefore selected accordingly.

4.4.12.3 Hydrant pressure variation

Variation in hydrant pressure is determined by selecting a minimum of three blocks. These should represent the highest, intermediate and lowest pressures. Typically they will be the off-takes hydraulically closest, in the middle and furthest respectively from the headworks.

In greatly undulating fields, the blocks with the highest, intermediate and lowest elevations may represent the greatest variation. In this case, and in very large blocks, assess these as well, giving a minimum of six blocks measured.

4.4.12.4 Lateral pressure variation

Variation in pressure along the lateral is assessed by taking pressure measurements *along representative laterals.* Three pressure measurements are taken from each lateral at the end, the middle, and the inlet. If two laterals are fed from the same hydrant, take the three measurements from each.

4.4.12.5 Station pressure variation

The variation in pressure across the entire station is determined from the above measurements. On small simple systems, a minimum total of 12 measurements will be used, comprised of three measurements from each of four blocks.

On larger or undulating systems, more pressure measurements will be used (six measurements from six or more blocks). Increasing the number of measurements will improve the quality of the results.

4.4.12.6 Lateral filter pressure loss

In-line filters or strainers fitted at the beginning of laterals can be the source of pressure variation either by inherent design or through becoming blocked.

If such filters are fitted, randomly sample five filters from the ‘dirtiest’ areas.

Record the pressure in each lateral with the filter in, then remove the filter element and record pressure with it out. Calculate pressure loss as the average of the five readings.

4.4.13 Sprinkler performance

4.4.13.1 Wetted radius

Determine the wetted length (extending to approximately 75% of the wetted radius of end sprinklers) and width (lane spacing) of the irrigated area.

4.4.13.2 Sprinkler pressure / flow

Measure the pressures and flows from at least 4 adjacent sprinklers near the middle of a single lateral. Avoid the inlet end as pressure variation will typically be too great 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 5 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.

4.4.13.3 Adjusted pressure test

The effect of pressure change on emitter flow is calculated using the discharge coefficient. If a manufacturer's value is unavailable, or is queried, the discharge coefficient can be determined from measurements of the same emitters at different operating pressures.

Repeat the sprinkler pressure / flow measurements after adjusting the lateral pressure by about 20%.

If the normal pressure is 50 – 80 kPa try to increase pressure, if necessary by closing down some sections of the station. If normal pressure is 100 – 140 kPa reduce pressure.

After this test, reset the system to its normal operating conditions.

4.4.13.4 Grid uniformity test – solid-set systems

Arrange a grid of collectors between three adjacent sprinklers in a representative part of the system. The grid will be centred on the lateral, extending just beyond the wetted width.

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

4.4.13.5 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 lateral (lane) spacing (D_s). 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 lateral (lane) 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.

4.4.13.6 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 but the duration must be sufficient to collect enough water for accurate measurement. The system must be shut off before collector readings begin.

4.4.14 Optional tests

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

4.4.15 Performance indicators

4.4.15.1 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 pressure and 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.

4.4.15.2 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.

4.4.15.3 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.

4.4.15.4 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.

4.4.16 Distribution uniformity

4.4.16.1 Field DU_{lq}

Estimate an overall field distribution uniformity by combining contributing variable factors, (grid uniformity, pressure flow variation and ponding factor) using simple multiplication.

$$FDU_{lq} = \left(GDU_{lq}\right)\times\left(QDU_{lq}\right)\times\left(F_{ponding}\right)$$

Where:

FDU_{lq} is low quarter field distribution uniformity

GDU_{lq} is low quarter grid distribution uniformity

QDU_{lq} is low quarter pressure flow distribution uniformity

$F_{ponding}$ is surface redistribution from ponding

4.4.16.2 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.

4.4.16.3 Pressure flow uniformity, QDU_{lq}

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

4.4.17 Uniformity coefficient

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

4.4.18 Application Depth

4.4.18.1 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.

4.4.18.2 Evaporation adjustment

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

4.4.18.3 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 .

4.4.18.4 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.

4.4.18.5 Irrigated area application depth

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.

4.4.19 Application rates

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

4.4.19.1 Instantaneous application rate

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

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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

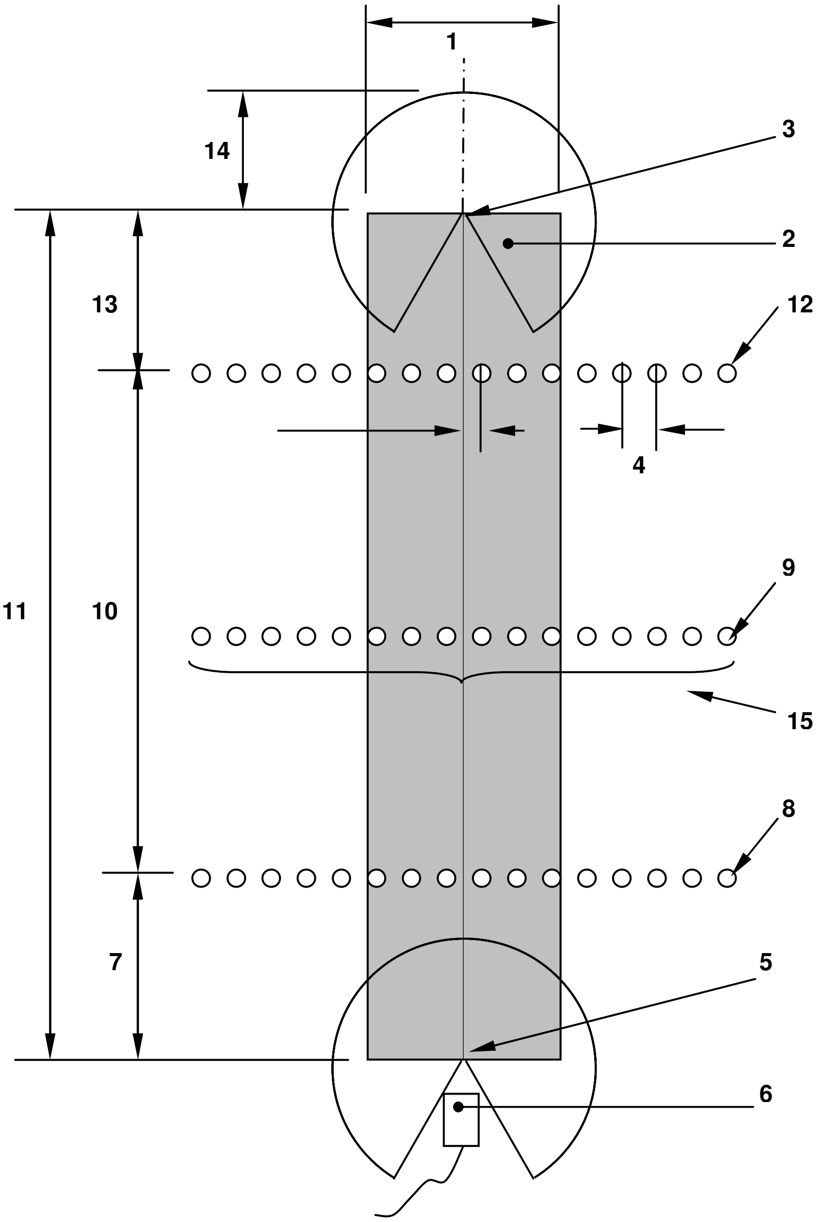
4.5.3.4 Related schedules and appendices

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° 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° 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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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.

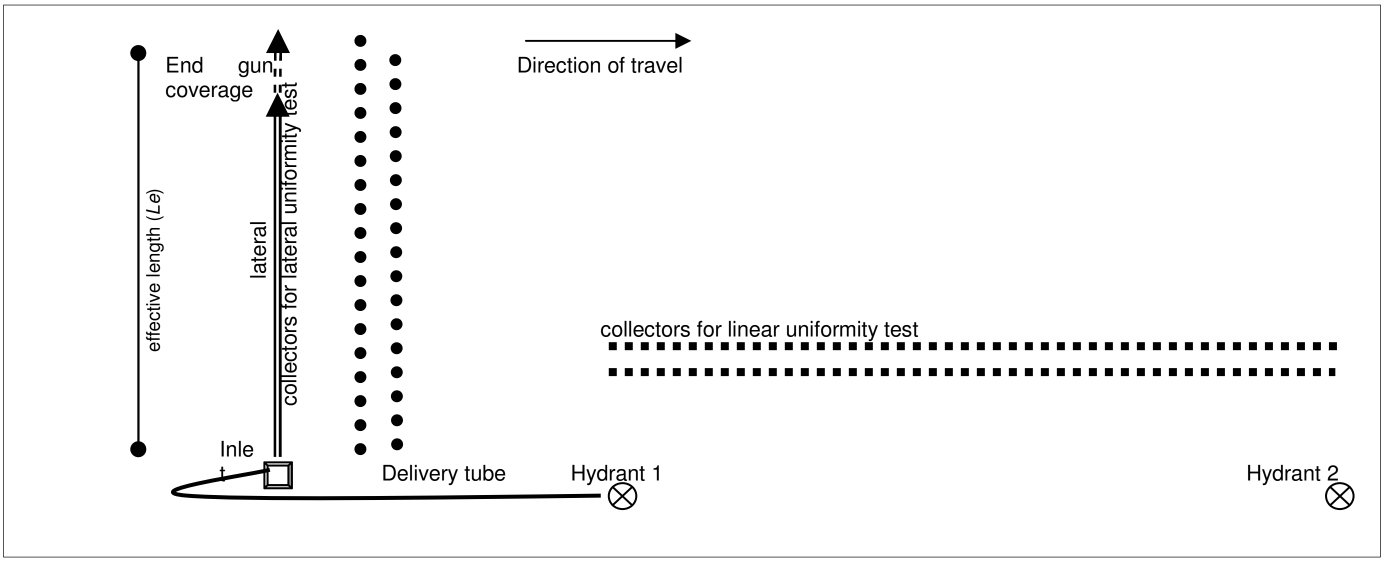

Figure 4.6.1: Collector placement for distribution uniformity test

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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Field evaluation of centre pivot irrigation machines

Table of Contents

4.6.1 System description

A centre pivot machine consists of a lateral circulating around a fixed pivot point. The lateral is supported above the field by a series of A-frame towers, each having two driven wheels at the base. Depending on field layout, the pivot may complete a full circle or only part segments.

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.

Centre pivot irrigation machines are used on over half the sprinkler irrigated land in the United States (CPD) and increasingly in New Zealand. They make irrigation feasible in many areas where other techniques are not suitable. Because of the very low labour requirement per irrigation, centre pivots allow farmers to apply frequent light irrigations as needed to best fit crop water requirements and maximise production.

4.6.1.1 This Schedule

This schedule outlines procedures to be followed when assessing distribution uniformity of a centre pivot 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.

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

4.6.2 Special features for analysis

4.6.2.1 Discharge rates along the lateral

The unique and critical feature of a centre pivot machine is how it moves across the field. The centre pivot lateral moves at increasing ground-speed with distance for the centre, so the application *rate* must increase further out along the lateral to give the same application *depth*.

Any point-measurement, such as a collector (catch-can) volume, is representative of a much larger area of the entire field. Under a centre pivot, the measurements at the outer end represent a very much larger area of the field than do those near the centre.

4.6.2.2 Stop-start operation

The speed of rotation of a centre pivot 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).

Irrigator alignment is maintained by operating inner towers for proportionally shorter times, so the forward movement of these machines is unsteady. 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 radial test this may require operating the machine at 100% speed to minimise the number and duration of stop-starts. Alternatively, multiple radial measurements can be used.

Hydraulically powered centre pivot machines should run more smoothly but assessors are advised to still pay attention to the possibility of erratic movement and potential effects on uniformity.

4.6.2.3 Field variability

The performance of a centre pivot irrigation machine may vary at different positions in the field. Contributing factors include topographic variation and elevation changes, wind effects, and the operation of various add-on components such as end guns or corner swing arms.

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.

4.6.3 Technical materials

4.6.3.1 Relevant standards

ANSI/ASAE S436.1 DEC01 *Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles (ANSI)*

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

Allen, R.G., J. Keller and D. Martin. 2000. *Center Pivot System Design.* The Irrigation Association. Falls Church, VA. (CPD)

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

New, L. and G. Fipps. 2002. *Center Pivot Irrigation.* Bulletin B-6096. 4.00. Texas Agricultural Extension Service. The Texas A&M University System. via internet: http://amarillo.tamu.edu/amaweb/Programs/EnviroSys-NatRes/IrrigaWtrQlty/publications/B-6096-CtrPivIrri.pdf

4.6.3.3 Abbreviations

Reference abbreviations used in text

Cal	Burt, Walker, Styles and Parrish. 2000
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4.6.3.4 Related schedules and appendices

Section 2	Conducting a field evaluation
Schedule 3	Seasonal irrigation efficiency assessment
Schedule 4.6	Linear move 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 centre pivot 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.

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.

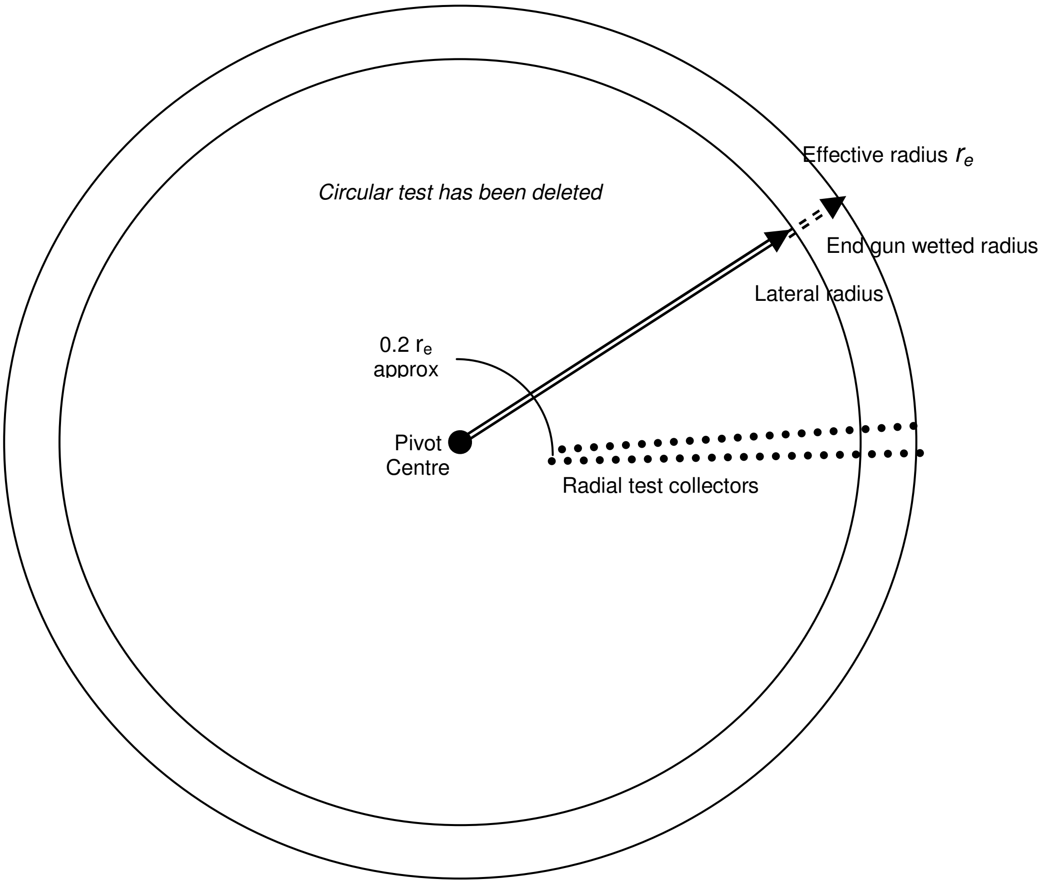

Fig 4.7.1. Layout for pivot uniformity tests

4.6.5.2 Site variability

If site elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several radial uniformity tests in different parts of the field.

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 examples **Fig. 4.1.1** and Fig 4.7.1).

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 radius (re)

Measure the effective radius from pivot centre (Fig 4.7.1).

4.6.6.6 Corner system wetted radius

Determine the effective wetted radius at full extension of any corner system fitted to the machine. Determine where it may be operative.

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.

Operate the centre pivot machine as near to 100% speed (Cal) while ensuring a reasonable average application depth for accurate collector volume measurements (ISO recommend 15mm).

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)

4.6.7.5 Corner system wetted radius

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

4.6.7.6 Field variability

If field elevation varies significantly, consider multiple tests to increase accuracy of distribution uniformity assessments. This may involve several radial uniformity tests.

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 represent those of 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 tower.

4.6.9.6 Ponding

Assess the amount of ponding particularly toward the end of the pivot where application rates are highest. Also check the centre where machine speeds are lowest. Note if water is ponding, running over the ground, or causing soil movement. Ponding can significantly reduce application uniformity in a field.

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. Runoff does not affect uniformity, but does reduce irrigation efficiency.

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

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 Normal speed (Sn)

Determine the typical time required to make one full-circle pass during periods of peak water use (Cal). This may be from farmer information or design specifications.

4.6.10.6 Test speed (St)

Measure the machine speed at 2/3rds effective radius – the centre point for mass discharge of the machine. This greatly simplifies comparisons between total machine flow (4.7.11.1) and measured application depths from uniformity measurements (4.7.15.5).

Measure the machine test speed at the end tower. Time how long it takes the machine to pass over the test track, and all intermediate start and stop times (IEP).

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 stabilises before taking any reading.

4.6.12 Pressure measurement

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 Pivot lateral pressure

With the system operating, measure lateral pressures upstream of any sprinkler pressure regulators:

- 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 or end 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.

4.6.12.3 Sprinkler pressure (pressure regulator function)

Check pressures of eight sprinklers using a pitot tube or in-line gauge downstream of any pressure regulator. This may require dismantling of the sprinkler unit to fit a temporary test point, or for access to the nozzle jet-stream.

With system operating, measure pressure at

- First sprinkler
- Last sprinkler (before end-gun)
- Highest sprinkler
- Lowest sprinkler
- Four other sprinklers randomly along the lateral

4.6.13 Sprinkler performance

For a centre pivot with overlapping sprayers or sprinklers, the only useful measurement of uniformity comes from catch can collectors. This is because such systems have a wide variety of sprinkler spacings and flow rates and more detailed analysis will be time consuming and expensive (Cal).

4.6.13.1 Sprinklers/sprayers

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.

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

4.6.13.2 Radial uniformity test

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

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

4.6.13.3 Collector placement

Paired radius test

Arrange two rows of collectors either side of a radial line starting about 20% of the way along the lateral. (The inner span represents a small proportion of irrigated area and flow rates are very low.)

Rows should be 3m apart at the inner-most collector (Fig 4.7.1 and Fig 4.7.2).

- If an end-gun is used, the rows of collectors should be extended to just inside the wetted radius.

Machines < 450m effective length: 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.

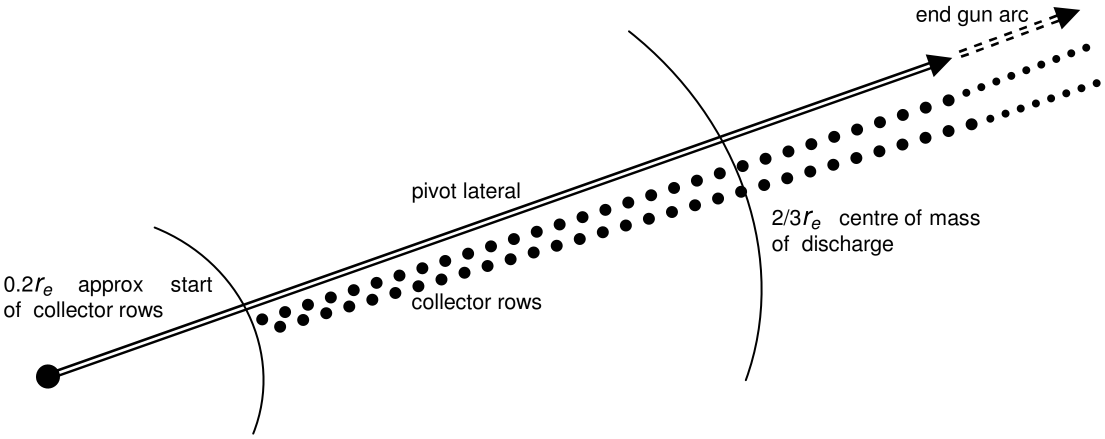

Fig 4.7.2 Collector placement for paired radial test

Machines > 450m effective length: Increase the number of collectors proportionally so mean collector spacing is about 5m.

- Measure and record the position of each collector relative to the pivot centre.
- Position collectors ahead of the irrigator, 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 collectors in wheel tracks.

4.6.13.4 Water collection – radial uniformity test

Collection and measurement can begin at the outer collector in the first wetted row, then progress in to the centre and back out again. This allows collection to begin as soon as possible, and while the last collector in the second row is still being wetted.

4.6.14 Optional tests

4.6.14.1 Circular uniformity test

The Circular Uniformity test recommendation has been removed from these protocols. Much variability will be due to radial (along the pivot length) variation rather than around the circle. Effort is better used repeating radial uniformity tests at different positions in the field.

4.6.14.2 Travel speed and pressure tests

Monitoring machine travel speeds and sprinkler pressures can provide useful information about machine performance and variability.

If the machine has sprinkler pressure regulators fitted and pressure is sufficient at all locations, flows should remain uniform. If travel speeds are also uniform around the circle, distribution uniformity should be constant unless sprinkler heights vary.

4.6.14.3 Repeat tests

Repeat tests to determine distribution uniformity with and without the end-gun operating, or with the pivot lateral in a different field location or locations. In particular, consider up slope regions where machine pressures may be reduced.

If sprinkler heights or system pressures vary, additional radial uniformity tests will give most reliable uniformity assessments.

4.6.15 Performance indicators

4.6.15.1 Distribution uniformity

Distribution uniformity is determined using the low quarter distribution uniformity coefficient, DU_{lq}. Because the lowest quarter relates to a proportion of total field area, not total collector number, calculations must be made to determine which collectors are representing the lowest quarter.

4.6.15.2 Uniformity Coefficient

If calculating statistical coefficient values, ensure modified formulae are used where, and only as, appropriate.

- **Radial uniformity coefficient (CUr)**

Calculate the Uniformity Coefficient using the modified formula of Heermann and Hein. This adjusts for the relative area represented by each collector (ISO, CPD).

4.6.15.3 Application depth

To make valid assessments of pivot performance, the depths measured by collectors must be adjusted to account for evaporation losses and weighted according to distance from the pivot centre.

4.6.15.4 Application rate

Application rates vary along the length of a centre pivot machine, as speeds are higher at greater radii. The average application rate occurs at approximately $2/3^{rds}$ the full radius. Half the total machine flow is discharged in the first $2/3^{rds}$ and the remainder in the outer $1/3^{rd}$.

Instantaneous application rates are calculated at $2/3^{rd}$ effective radius and at the end of the pivot. Rates are compared to soil infiltration rates providing 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.

Centre pivots uniquely require a weighting to be applied to collector results. This accounts for the greater field area represented by collectors more distant from the pivot centre.

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 radial 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 Radial distribution uniformity, $RadDU_{lq}$

Determine radial low quarter distribution uniformity from evaporation adjusted collector depths using the Distance adjusted DU_{lq} Eqn 31.

4.6.17 Other uniformity factors

4.6.17.1 Sprinkler discharge uniformity

Testing sprinklers is not viable as the performance of each necessarily varies from the rest. It is not feasible to determine desired flows without a specific analysis / design program.

4.6.17.2 Uniformity coefficient – radial test

Calculate the statistical uniformity coefficient for radial tests based on the Heermann-Hein modified Uniformity Co-efficient Eqn 34.

4.6.18 Application Depth

4.6.18.1 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 increasing distance from pivot centre (see 4.7.16.3).

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 using Eqn 43.

4.6.18.4 Collector application depth

Calculate the mean application depth within the radial test zone, after adjusting for evaporation and distance from pivot centre.

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

4.6.19 Application rates

The application rates under a centre pivot increase with distance form the pivot centre.

The instantaneous application rate may be calculated using the flow and area determined for the entire irrigated circle.

4.6.19.1 Instantaneous application rates

Calculate the maximum instantaneous application rates Eqn 49 at:

- the centre of mass of discharge,
- the end of the lateral, and
- the end of the effective radius.

4.6.20 Pressure variation

4.6.20.1 Mainline pressures

For towable centre pivots:

Measure the available pressure at each hydrant and calculate the percentage variation.

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 pivot 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 (4.7.12.3).

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

5 Appendices

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5.1 Glossary

5.1.1 Terms and Definitions

Adjusted depth (d_i)	Adjusted volume of water caught in each collector in an array of collectors plus the average amount of water that evaporates while the water is in the collector, divided by the area of the collector opening (ISO)
Applied depth (D_{app})	The volume of water applied divided by the wetted area (Aw). On a single plant or emitter scale volume is measured in litres, area in square meters giving applied depth in millimetres (mm)
Block	A section of the irrigation system served by a single off-take, and comprising a manifold and its attached laterals. [See also: Station]
Coefficient of variation (C_v)	A statistical measure of variation within a sample
Crop Irrigation Demand (CID)	The amount of water that would potentially be consumed by the irrigated crop in one week during peak evapo-transpiration conditions (m3/ha/week)
Delivery hose	(= FDIS 'Distribution hose', In-field supply hose, Softwall supply hose) Supply line that conveys water along an irrigated strip to a traveller irrigation machine
Delivery tube	(= FDIS 'Distribution tube', In-field supply tube, Polyethylene tube) Supply line that conveys water along an irrigated strip to the water distribution system of reel and self-propelled reel machines
Design system capacity (SC_{des})	The flow of water per hectare of irrigated area used in the design of the system.
Discharge coefficient (k_d)	A dimensionless measure of the sensitivity of the emitter flow rate to changes in pressure
Discharge exponent (x)	A dimensionless measure of the sensitivity of the emitter flow rate to changes in pressure
Distance adjusted lowest quarter determination (D_{ajq})	Lowest quarter of collectors determined by ranking collected volumes and adjusting for distance from the pivot centre
Drive test pressure (P_d)	Pressure of a traveller irrigation machine measured at the inlet to the hydro-dynamic drive (FDIS)
Effective length (L_e)	Dimension parallel to the pipeline of the area to be irrigated by a linear move irrigation machine, conventionally calculated as the distance between the two most distant sprayers or sprinklers on the pipeline plus 75% of the wetted radius of the terminal sprayers or sprinklers. Where a proportion of the area under the pipeline is used for the water supply system and not crop production, that distance is excluded from the effective length (ISO)
Effective radius (r_e)	Radius of the circular field area to be irrigated by a centre pivot, conventionally calculated as the distance from the pivot point to the terminal sprayer or sprinkler on the pipeline plus 75% of the wetted radius of the terminal sprayer or sprinkler (ISO)
Emission uniformity (EU)	A measure of variability in flow from emitters that is based on the coefficient of variation. Corresponds mathematically to the Christiansen coefficient
Emitter	A device used to control the discharge from a lateral line at discrete or continuous points (ASAE 458).
Emitter emission uniformity (EEU_{lq})	A measure of the variability of flow being received by individual plants. Derived from EU_{man}, EU_{defect} and the number of emitters per plant, equated to a low quarter uniformity equivalent
End-gun	Set of one or more sprayer or sprinkler nozzles installed at the distal end(s) of an irrigation machine to increase the irrigated area, and usually operating for only a portion of the time to conform to system boundaries (ISO)
Equivalent applied depth (Dz_{app})	In drip-micro irrigation, the volume applied to a plant, adjusted for the allocated ground area per plant
Inlet test pressure (P_i)	Pressure of a traveller irrigation machine measured at the inlet to the machine (FDIS)

Irrigation requirement (IR)	Crop water requirement plus any additional beneficial water requirement less received precipitation and stored soil moisture
Irrigation strip	(Irrigation set) The portion of a field irrigated by a sprayline or travelling irrigator set up in one location. It typically consists of a rectangle with an effective zone wetted by the water distribution system that significantly exceeds the dimensions of the strip and especially the width. Some overlapping of the wetted patterns of adjacent strips is often required to maintain an acceptable uniformity of water application over the entire field (~FDIS)
Irrigation strip width (E)	(Strip spacing, Set spacing) The spacing between strips, i.e. distance between two adjacent travel paths of the gun-cart or between two adjacent sprayline positions (~FDIS).
Lateral	An emitting pipe with uniformly decreasing flow supplying water to points of application (~ASAE 458). In drip-micro systems: The hose or tube, typically made of polyethylene, with emitters integrated or attached. In spraylines, linear moves and pivots: The pipe, typically made of steel or aluminium, on which sprinklers or sprayers are mounted.
Lateral filter	In-line filter or screen fitted at the beginning of each lateral line.
Lateral pressure (P_s)	Pressure available at a point in the lateral measured, while the system is in normal operation, using a pitot tube fitted to a gauge.
Line-source emitters	Water is discharged from closely spaced perforations, emitters or a porous wall along the lateral (ASAE 405.1).
Low quarter irrigation adequacy (IA_{lq})	The ratio of the mean low quarter depth applied, to the mean target depth required across the field as a whole
Mainline	A pipeline that carries treated water from system headworks to off-takes supplying a series of blocks.
Manifold	A pipe usually of polyethylene or PVC that carries water from an off-take to a number of laterals.
Manufacturing emission uniformity (EUman)	Description of variation in flow resulting from manufacturing variability, determined from physical laboratory measurements at a standard temperature.
Maximum allowable deficit (MAD)	The proportion of total available water that can be used by the crop before yield reducing stress is induced. Also called Management allowable depletion (%)
Mean field application depth (D_{mf})	Mean application depth collected along transverse lines after adjustment for evaporation and overlap from adjacent strips (~FDIS)
Micro-irrigation system	Physical components required to apply water by micro-irrigation, consisting of a number of low pressure polyethylene laterals connected to manifolds and mainlines, and through which water is applied through point source emitters located along the laterals for further redistribution by the soil medium.
Operating system capacity (SC_{op})	The flow of water per hectare of irrigated area that can be supplied in the time that the system is operating.
Percentage wetted area	The area wetted as a percentage of the total crop area (ASAE405)
Point-source emitters	Water is discharged from emission points that are individually and widely spaced, usually over 1 metre apart. Multiple-outlet emitters discharge water at two or more emission points (ASAE 405.1).
Potential low quarter application efficiency (PAElq)	A single event potential application efficiency estimated from field distribution uniformity and surface losses due to runoff and leakages. The value calculated can be used to determine the scheduling co-efficient.
Pressure regulation point	A location at which system pressure is managed to fall within defined parameters, typically through automatic or manually adjusted pressure regulation valves or by pipeline design. A pressure regulation point will normally be a block off-take or inlet to a manifold.
Readily available water (RAW)	The amount of water held between field capacity and stress point, available to plants without yield inducing stress.

Reference application rate (R_i)	The mean rate of water application to the wetted area calculated from mean application depth, wetted area and irrigation duration (~FDIS)
Required system capacity (SC_{req})	The flow of water per hectare of irrigated area required to replace water used by the crop (plus any additional amounts for other purposes) in the time available.
Return interval (RI)	The time period between the beginning of one irrigation event and the next on a crop or area in question (days)
Rotator	A sprinkler that distributes water through a jet formed by parts that rotate at controlled speed
Seasonal application efficiency (SAE)	The ratio of water retained in the root zone to water applied to the field, over a full irrigation season or year.
Seasonal deep percolation (SDP)	Includes all drainage whether from irrigation or precipitation
Seasonal irrigation deep percolation (SDPi)	A measure of the amount of irrigation water applied that drains from the soil profile. It is, in effect, seasonal application in-efficiency
Spinner	A sprinkler which distributes water, utilising free rotational movement of the sprinkler parts, in the form of a stream that breaks into droplets.
Sprayer	A sprinkler which sprays water, without rotational movement of the sprayer parts, in the form of fine jets or in a fan shape (ISO 8026).
Sprinkler	Generic label for a device that distributes pressurised water through the air to a surrounding area
Sprinkler package	Collection of devices fitted to the outlets of an irrigation machine or system potentially consisting of sprayers or sprinklers and potentially including piping, pressure or flow-control devices and supporting plumbing designed for a specific irrigation machine and set of operating parameters (ISO)
Sprinkler pressure (P_s)	Pressure available at an individual sprinkler measured just upstream of the sprinkler or at the outlet, in the centre of the jet and 3mm from the orifice.
Sprinkler pressure (P_S)	(Guns) Pressure of a traveller irrigation machine measured at the inlet to the gun or sprinklers of the distribution system (ISO 8026, FDIS)
Station (Subunit)	A section of the irrigation system consisting of main, manifold and lateral pipelines which operate simultaneously and have independent flow control. A station is operated as a single unit and potentially comprises a number of blocks. When the system is running, every emitter in the station and no emitter outside the station should be discharging water.
System capacity (SC)	The flow of water per hectare of irrigated area required to replace water used by the crop (plus any additional amounts for other purposes) in the time available.
Test pressure (P_t)	Pressure of a linear move or centre pivot irrigation machine measured at the first available outlet downstream of the elbow or tee at the top of the inlet structure (ISO)
Total available water (TAW)	The amount of water held in the soil between field capacity and permanent wilting point. (mm/100mm or mm)
Travel path	Path within a strip along which the delivery tube or cable is laid and the gun-cart travels (~FDIS)
Travel path length (L_t)	Distance a traveller irrigation machine moves along its travel path, from starting point to stopping point, being not more than the length of the delivery tube for reel or self propelled reel machines, and not more than twice the delivery hose length of traveller machines (~FDIS)
Wetted area (A_w)	The average soil area wetted by a single emitter, estimated in the root zone from the surface to a depth of <50cm (~Cal)
Wetted radius (r_w)	Distance measured from the centre line of a sprayer or sprinkler to the furthest point at which the application rate of the individual nozzle declines to approximately 1mm/hour, based on tests conducted when there is no wind (ISO)
Water distribution system	Sprinkling and travelling part of a traveller irrigation machine by which water is distributed and applied over a strip (FDIS). (e.g. sprinkler or gun-type sprinkler, combination of sprinklers and guns, boom with a set of sprinklers, sprayers or other kinds of water distribution devices)

Of a solid set or sprayline system: the arrangement of sprinklers used to distribute water across the area to be irrigated.

5.1.2 Abbreviations and Symbols

A	area of the irrigated strip (m^2)
A_{plant}	ground area per plant
ASM	available soil moisture
A_w	Wetted area
A_{wetted}	wetted area per emitter
CU_c	Christiansen coefficient of uniformity
CU_r	Heermann and Hein coefficient of uniformity
C_v	coefficient of variation
Cv_{defect}	coefficient of variation due to emitter blockages, wear and tear
Cv_{man}	coefficient of variation due to manufacturing
Cv_{QPadj}	coefficient of variation of pressure adjusted flows
$\overline{D}$	mean depth of water collected by all collectors used in the data analysis
$\mathrm{D_{ajq}}$	Distance adjusted lowest quarter determination
D_{app}	Applied depth
Dc	critical deficit
d_f	Mean field application depth
d_i	Adjusted depth
D_{inf}	depth water infiltrates
d_{lq}	low quarter applied depth
D_{mf}	mean application depth based on system flow rate (mm)
d_{target}	targeted application depth
D_{wa}	average depth of water applied
D_{wr}	average depth of water retained
D_{Zmean}	mean depth applied to the whole field
Dz_{app}	Equivalent applied depth
D_{Zmin}	minimum depth applied to a zone
DP	deep percolation in periods 1 to n
DU_{lq}	low quarter Distribution uniformity
E	Irrigation strip width
EC_{vol}	volumetric energy consumption
Dz_{app}	Applied Depth in an area
EEU_{lq}	emitter variation factor
$E_{hydraulic}$	hydraulic efficiency
E_{pump}	pump efficiency
ET_{crop}	crop water use by evapo-transpiration
$ET_{limited}$	crop water use by a crop with restricted available soil moisture
EU	statistical emission uniformity
EU_{man}	manufacturer's emission uniformity
F_{dr}	drought response factor (%yield / mm PSMD)
$F_{drainage}$	effect of unequal system drainage
$F_{spacing}$	effect of spacing
F_{runoff}	proportion of water that leaves the field as a result of overland flow
FDU	Field Distribution Uniformity, an overall value incorporating a range of uniformity factors
GDU	Grid Distribution Uniformity, calculated from adjusted depths from a grid of collectors
I_i	Reference application rate
IA_{lq}	low quarter irrigation adequacy
IR	irrigation requirement
K_{lq}	statistical distribution parameter for a normal distribution when low quarter is fraction used

K_d	emitter discharge coefficient
L_e	Effective length
L_t	Travel path length
MAD	management allowed depletion, maximum allowable deficit
n	number of items used in the data analysis
N_e	number of emitters per plant
n_{ER}	percentage of emitters that run after system shut down
OTA	depth equivalent of off-target application (mm)
p	operating pressure
P	precipitation
P_d	Drive test pressure
P_{energy}	price paid for energy ($/kWhr)
P_{field}	mean pressure determined from whole field pressure tests
P_i	Inlet test pressure
P_s	Sprinkler pressure
$\mathrm{PAE}_{\mathrm{lq}}$	Potential low quarter application efficiency
PET	Potential evapo-transpiration
PSMD	potential soil moisture deficit (mm)
P_t	Test pressure
P_{test}	pressure at which block was flow tested
P_w	price paid for water ($/m^3)
q	emitter flow rate
Q_{Em}	measured emitter flow
Q_{Padj}	Pressure adjusted emitter flow
Q_m	system flow rate (m^3/h)
Q_x	average flow per emitter
r_e	Effective radius
R_{ir}	reference application rate (Assumed constant)
R_{it}	instantaneous application rate for transect *i* (mm/hr)
r_w	Wetted radius
RI	Return interval
RO	depth equivalent lost through run-off (mm)
RAW	readily available water
s	standard deviation in the sample
SAE	seasonal application efficiency
S_{cc}	spacing between collector columns
SC_{des}	design system capacity
SC_{op}	operating system capacity
SC_{pot}	potential system capacity
SC_{req}	required system capacity
SDP	seasonal deep percolation
SDP_i	seasonal deep percolation from irrigation (mm)
$\mathrm{SDU}_{\mathrm{lq}}$	low quarter system distribution uniformity
SMD	soil moisture deficit
T_{ER}	average time for which those emitters run after system shut down
T_{irrig}	duration of an irrigation event
TAW	Total available water
$\overline{V}$	arithmetic average volume (or alternatively mass or depth) of water collected by all collectors used in the data analysis
Va_{lq}	distance adjusted average volume (or alternatively the mass or depth) of water collected in the lowest quarter of the field, calculated

V_i	volume (or alternatively the mass or depth) of water collected in the *i*th container
V_{ww}	value of wasted water ($/mm/ha)
WHC	soil water holding capacity
WR_b	beneficial water requirement applied by irrigation system
X	emitter discharge exponent
$\bar{x}$	mean value from the sample
YL_{di}	drought induced yield loss
Y_{pot}	Potential Yield (t/ha)

5.2 Calculations

5.2.1 Standard formulae

5.2.1.1 Water and soil calculations

Eqn 1 Crop evapotranspiration (ET_{crop})

The crop water requirement calculated is described as crop-adjusted evapo-transpiration (ET_{crop}), by adjusting PET to account for crop specifics and ground cover.

$$ET_{crop} = PET \times K_c$$

Where

ET_{crop}	is crop-adjusted evapo-transpiration (mm/d)
PET	is reference potential evapo-transpiration (mm/d)
K_c	is the crop water use co-efficient

And $Kc = K_{crop} \times K_{gc}$

Where

K_{crop}	is crop specific water use factor
K_{gc}	is the ground cover fraction

Eqn 2 Crop water use ($ET_{limited}$)

Actual crop water use is a function of PET, limited by soil available water. Potential water use in any period is given by ETcrop. Where soil moisture is limited, the actual water use will be the maximum of ETcrop or available soil moisture (ASM)

$$ET_{limited} = \text{greater of: } ET_{crop} \text{ or } ASM + (P+I)$$

Where

$ET_{limited}$	is actual crop water use
ET_{crop}	is crop water use by evapo-transpiration
ASM	is available soil moisture
I	is beneficial water requirement applied by irrigation system
P	is precipitation

Eqn 3 Potential soil moisture deficit (PSMD)

Potential crop growth is reduced in any period where crop water use is restricted due to low soil water availability. PSMD is a measure of moisture stress experienced by a crop, relative to the climatic potential moisture use. PSMD can be estimated from Potential crop water use (ET_{crop}) and actual (water limited) crop water use ($ET_{limited}$).

$$PSMD = ET_{crop} - ET_{\lim ited} : ET_{crop} > ET_{\lim ited}$$

Where:

$PSMD$	is potential soil moisture deficit in any period where $SMD>D_c$
ET_{crop}	is crop water use by evapo-transpiration
$ET_{limited}$	is actual crop water use

5.2.1.2 System capacity calculations

Eqn 4 Design system capacity (SC_{des})

The flow of water per hectare of irrigated area determined by the designer of the system. Presumed to be the basis for the subsequent design. The value would normally be selected based on need to replace water used by the crop plus any additional amounts for other purposes. However water source limitations or regulatory maxima may necessitate a lower value.

Eqn 5 Required system capacity (SC_{req})

The flow of water per hectare of irrigated area required to replace water used by the crop (plus any additional amounts for other purposes) in the time available.

$$\mathrm{SC}_{\mathrm{des}} = \frac{\mathrm{PET} \times \mathrm{K_c} \times 24 \times 3600}{10{,}000} \times \frac{T_{irrig}}{T_{rot}}$$

Where

SC_{des}	is design system capacity (L/s/ha)
PET	is reference potential evapo-transpiration (mm/d)
K_c	is the crop water use co-efficient
T_{irrig}	is time irrigating per rotation (hrs)
T_{rot}	is time per rotation (hrs)

Eqn 6 Potential system capacity (SC_{pot})

The flow of water per hectare of irrigated area that can be supplied if the system as operating was run for 24 hours per day. It is calculated from measured or calculated system flow rate divided by the measured or calculated area irrigated.

$$\mathrm{SC}_{\mathrm{pot}} = \frac{Q_{sys}}{A_{irrig}}$$

Where

SC_{pot}	is potential system capacity (L/s/ha)
Q_{sys}	is the mean system flow rate ((L/s)
A_{irrig}	is area irrigated (ha)

Eqn 7 Operating system capacity (SC_{op})

The flow of water per hectare of irrigated area that can be supplied in the time that the system is operating. It is the potential system capacity adjusted by the ratio of time irrigating per rotation to rotation time.

$$\mathrm{SC}_{\mathrm{op}} = SC_{pot} \times \frac{T_{irrig}}{T_{rot}}$$

Where

SC_{op}	is operating system capacity (L/s/ha)
SC_{pot}	is potential system capacity (L/s/ha)
T_{irrig}	is time irrigating per rotation (hrs)
T_{rot}	is time per rotation (hrs)

5.2.1.3 Efficiency calculations

Eqn 8 Seasonal application efficiency

Seasonal application efficiency (SAE) is given by the ratio of water retained in the root zone to water applied to the field, over a full irrigation season or year.

$$SAE = \frac{\overline{D}_{wr}}{\overline{D}_{wa}} \times 100$$

Where

SAE is the seasonal application efficiency

D_{wr} is the average depth of water retained

D_{wa} is the average depth of water applied

Eqn 9 Weighted seasonal application efficiency (SAEw)

The overall SAE is a weighted average of these calculated values.

$$SAE_w = \frac{AE_{lq} + 2AE_{mean} + AE_{hq}}{4} \times 100$$

Where

SAE_w is weighted seasonal application efficiency

$_{lq}$ is low quarter zone

$_{mean}$ is field average zone

$_{hq}$ is high quarter zone

Eqn 10 Potential low quarter application efficiency (PAElq)

The single event potential application efficiency is estimated from field distribution uniformity and surface losses due to runoff and leakages. The value calculated can be used to determine the scheduling co-efficient.

$$PAE_{lq} = DU_{lq} \times (1.0 - (RO + SL))$$

Where

PAE_{lq} is potential low quarter application efficiency

DU_{lq} is low quarter distribution uniformity

RO is field runoff

SL is system leakages

Eqn 11 Low quarter irrigation adequacy (IA_{lq})

The ratio of the mean low quarter depth applied, to the mean target depth required across the field as a whole.

$$AD_{lq} = \frac{d_{lq}}{d_{t\arg et}}$$

Where

IA_{lq} is low quarter irrigation adequacy

d_{lq}	is low quarter applied depth
d_{target}	is targeted application depth

Eqn 12 Seasonal potential soil moisture deficit ($PSMD_{season}$)

Seasonal PSMD is calculated by summing period PSMD's calculated as in Eqn 3.

$$PSMD_{season} = \sum \left(PSMD_1 : PSMD_n \right)$$

Where

$PSMD_{season}$	is seasonal potential soil moisture deficit
$PSMD_1$	is potential soil moisture deficit in the first period
$PSMD_n$	is potential soil moisture deficit in the n^{th} period

And where

$$PSMD_2 > PSMD_1$$

Eqn 13 Seasonal deep percolation (SDP)

Includes all drainage whether from irrigation or precipitation. It is estimated from the balance of water not retained in the root zone, calculated after any surface losses have been accounted for.

$$SDP = \sum \left(DP_1 : DP_n \right)$$

Where:

SDP	is seasonal deep percolation
DP	deep percolation in periods 1 to n

Eqn 14 Seasonal irrigation deep percolation (SDP_i)

Seasonal deep percolation resulting from irrigation is a measure of the amount of irrigation water applied that drains from the soil profile. It is, in effect, seasonal application in-efficiency.

$$SDP_i = (1 - SAE)$$

Where:

SDP_i	is seasonal deep percolation from irrigation
SAE	is seasonal application efficiency (Eqn 8)

Eqn 15 Drought induced yield loss (YL_{di})

Calculated from potential (farmer expected) yield, PSMD and the drought response factor:

$$YL_{di} = Y_{pot} \times PSMD \times F_{dr}$$

Where:

YL_{di}	is drought induced yield loss
Y_{pot}	is the Potential Yield (t/ha)
$PSMD$	is potential soil moisture deficit (mm)
F_{dr}	is the drought response factor (%yield / mm PSMD)

Eqn 16 Value of lost yield (YL_v)

The value of lost yield is determined from the value of the crop and the amount of lost yield.

$$YL_v = YL_{di} \times Price$$

Where:

YL_v	is the value of lost yield ($/ha)
YL_{di}	is drought induced yield loss

Price	is price paid per unit yield

Eqn 17 Value of wasted water (V_{ww})

One estimate of the cost of water non-beneficially used is to multiply the amount of irrigation water lost through deep percolation, runoff and off-target application by the price paid for the water.

$$V_{ww} = 10 \times (SDP_i + RO + OTA) \times P_w$$

where:

V_{ww}	is the value of wasted water (\$/mm/ha)
SDP_i	is seasonal deep percolation from irrigation (mm)
RO	is depth equivalent lost through run-off (mm)
OTA	is depth equivalent of off-target application (mm)
P_w	is the price paid for water (\$/m^3)
10	constant converting m^3/ha to mm/ha

Eqn 18 Value of wasted energy (V_{we})

$$V_{we} = \frac{10 \times (SDP_i + RO + OTA) \times (EC_{vol} \times P_{energy})}{\left(E_{pump} \times E_{hydraulic}\right)}$$

where:

V_{we}	is the value of wasted water (\$/mm/ha)
SDP_i	is seasonal deep percolation from irrigation (mm)
RO	is depth equivalent lost through run-off (mm)
OTA	is depth equivalent of off-target application (mm)
EC_{vol}	is volumetric energy consumption
P_{energy}	is the price paid for energy (\$/kWhr)
E_{pump}	is pump efficiency
$E_{hydraulic}$	is hydraulic efficiency
10	constant converting m^3/ha to mm/ha

Eqn 19 Irrigation requirement (*IR*)

Irrigation requirement is given by crop water requirement plus any additional beneficial water requirement less received precipitation and stored soil moisture.

$$IR = \frac{(ET_{crop} + WR_b)}{\left(DU_{lq}\right)} (P + ASM)$$

Where:

IR	is irrigation requirement
ET_{crop}	is crop water use by evapo-transpiration
WR_b	is beneficial water requirement applied by irrigation system
P	is precipitation
ASM	is available soil moisture
DU_{lq}	is low quarter Distribution uniformity

5.2.1.4 Base calculations

Eqn 20 Coefficient of variation (Cv)

The coefficient of variation is a statistical measure of variation within a sample, calculated using the formula:

$$C_v = \frac{s}{\bar{x}}$$

where

C_v	is the coefficient of variation
s	is the standard deviation in the sample
$\bar{x}$	is the mean value from the sample

and

Eqn 21 Standard deviation from the mean (s)

$$s = \left[\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1} \right]^{1/2}$$

where

x_i	is the performance of an individual within the sample
i	is a number assigned to identify a particular individual
n	is the number of individuals in the sample

A Cv of 0.05 implies 68% of flows are within 5% of the mean, and 95% of flows within 10% of the mean (DAM).

Eqn 22 Emitter pressure flow relationship

The relationship between emitter operating pressure and flow rate is given by the equation:

$$q = K_d p^x$$

where

q	is the emitter flow rate
K_d	is the emitter discharge coefficient
p	is operating pressure
x	is the emitter discharge exponent

Eqn 23 Emitter discharge exponent

The emitter discharge exponent can be determined using the formula (DAM):

$$x = \frac{\log\left(\frac{q_1}{q_2}\right)}{\log\left(\frac{p_1}{p_2}\right)}$$

where

x is the emitter discharge exponent

p_1 & p_2 are pressures

q_1 & q_2 are flows at p_1 & p_2 respectively.

The coefficient is typically between 0 and 1, often in the range 0.5 – 0.7.

A coefficient value = 0 describes an emitter where flow is totally independent of pressure, and a value = 1 describes an emitter where flow increases directly in proportion to pressure.

Eqn 24 Emitter discharge coefficient (K_d)

The emitter discharge coefficient is determined from the rearranged pressure flow equation:

$$K_d = \frac{q}{p^x}$$

where terms are as above.

Eqn 25 Manufacturer's emission uniformity (EU_{man})

Manufacturer's emission uniformity is determined from physical laboratory measurements at a standard temperature.

Values of EU_{man} are typically reported as a percentage value, but should be converted to a decimal. EU_{man} is derived from the coefficient of variation using the formula:

$$EU_{man} = 1.0 - Cv_{man}$$

where

EU_{man} is manufacturer's emission uniformity

Cv_{man} is the coefficient of variation in manufacturing

5.2.1.5 Combination formulae

Eqn 26 Weighted averages

When combining data from seasonal irrigation estimates that split into low quarter, mean and high quarter calculations it is necessary to apply a weighted average method.

$$X_{field} = \frac{X_{lq} + 2X_{mean} + X_{hq}}{4}$$

Where:

X_{field} is the overall result for the field for any particular parameter, X

X_{lq} is the result for the area receiving the low quarter irrigation

X_{mean} is the result for the area receiving the mean irrigation

X_{hq} is the result for the the area receiving the high quarter irrigation

See also Eqn 9

Eqn 27 Clemmens-Solomon

Combination of uniformity components where their influence is multiplicative should use the Clemmens-Solomon statistical procedure:

$$SDU_{lq} = \left[1 - \sqrt{(1 - DU_1)^2 + (1 - DU_2)^2 + (1 - DU_n)^2}\right]$$

Where:

SDU_{lq} is low quarter system distribution uniformity

DU_n is low quarter distribution uniformity of factor n

Examples include combining Pressure DU and emitter manufacturing DU.

Eqn 28 DU of combined populations

Where several populations are to be combined to determine an overall uniformity, the all data should be aggregated and a new DU determined from the whole data set.

It is not correct to take a simple mean of several DU’s to find an overall value.

If, for example, three areas (three drip blocks or three traveller transects) each had perfect DU (DU=1.00) but the measured application depths were different in each, the overall DU is not DU=1.00, but some lower value.

5.2.1.6 Uniformity calculations

Eqn 29 Distribution uniformity *(DU_{lq})*

This Code adopts the low quarter distribution uniformity ratio.

The low quarter distribution uniformity coefficient formula is:

$$DU_{lq} = \frac{\overline{V_{lq}}}{\overline{V}}$$

where

DU_{lq}	is the lowest quarter distribution uniformity coefficient
V_{lq}	is the average volume (or alternatively the mass or depth) of water collected in the lowest quarter of the field
$\overline{V}$	is the average volume (or alternatively mass or depth) of water collected by all collectors used in the data analysis

Eqn 30 Distance adjusted lowest quarter determination (D_{adj})

The distance adjusted lowest quarter of collectors is determined by ranking collected volumes and adjusting for distance from the pivot centre.

1. Rank all evaporation adjusted collector volumes, *V*.
2. Multiply each adjusted volume by its distance from the centre (*S*) to give the Distance adjusted volume *Va*.
3. Sum distances from pivot centre (*Si*) cumulatively from the lowest value. Divide by four to determine the low quartile point.
4. The low quarter is all the results at or below the low quartile point.

Eqn 31 Centre pivot radial uniformity

The low quarter distribution uniformity coefficient formula is adjusted to account for increasing field areas represented by collectors placed further from the pivot centre.

$$DU_{lq} = \frac{\overline{Va_{lq}}}{\overline{Va}}$$

where

DU_{lq}	is the lowest quarter distribution uniformity coefficient
Va_{lq}	is the distance adjusted average volume (or alternatively the mass or depth) of water collected in the lowest quarter of the field, calculated as:

Eqn 32 Distance adjusted average volume

$$\overline{Va_{lq}} = \frac{\sum_{i=1}^{n/4} Va_i S_i}{\sum_{i=1}^{n/4} S_i}$$

Where:

i	is a number assigned to identify a particular collector, normally beginning with the collector with the lowest catch volume (i = 1) and ending with i = n for the collector with the highest catch volume

n is the number of collectors used in the data analysis

S_i is the distance of the ith collector from the pivot point

$\overline{Va}$ is the distance adjusted average volume (or alternatively mass or depth) of water collected by all collectors used in the data analysis, calculated as:

$$\overline{Va} = \frac{\sum_{i=1}^{n} Va_i S_i}{\sum_{i=1}^{n} S_i}$$

Eqn 33 Christiansen coefficient (CU_c)

The Christiansen formula is:

$$CU_c = \left[1 - \frac{\sum_{i=1}^{n} \left| V_i - \overline{V} \right|}{\sum_{i=1}^{n} V_i}\right]$$

Where

CU_c is the Christiansen coefficient of uniformity

n is the number of collectors used in the data analysis

i is a number assigned to identify a particular collector

Vi is the volume (or alternatively the mass or depth) of water collected in the ith container

$\overline{V}$ is the arithmetic average volume (or alternatively mass or depth) of water collected by all collectors used in the data analysis, calculated as:

$$\overline{V} = \frac{\sum_{i=1}^{n} V_i}{n}$$

Eqn 34 Heermann-Hein uniformity coefficient

The Christiansen uniformity coefficient formula is adjusted as proposed by Heermann and Hein to account for increasing field areas represented by collectors placed further from the pivot centre.

The Heermann and Hein formula is:

$$CU_r = \left[1 - \frac{\sum_{i=1}^{n} \left| V_i - \overline{V_w} \right| S_i}{\sum_{i=1}^{n} \left| V_i S_i \right|}\right]$$

where

CU_r is the Heermann and Hein coefficient of uniformity

n	is the number of collectors used in the data analysis
i	is a number assigned to identify a particular collector, normally beginning with the collector located nearest the pivot point (i = 1) and ending with i = n for the collector furthest from the pivot point
V_i	is the volume (or alternatively the mass or depth) of water collected in the ith container
S_i	is the distance of the ith collector from the pivot point
$\overline{V_w}$	is the weighted average volume (or alternatively mass or depth) of water collected, calculated as:

$$\overline{V_w} = \frac{\sum_{i=1}^{n} V_i S_i}{\sum_{i=1}^{n} S_i}$$

Eqn 35 Emission uniformity (*EU*)

Corresponds mathematically to the Christiansen coefficient and is based on the coefficient of variation using the formula:

$$EU = (1.0 - Cv)$$

where

EU	is the statistical emission uniformity
Cv	is the coefficient of variation

Eqn 36 Emission v's Distribution Uniformity

Emission uniformity (EU) is related to low quarter distribution uniformity (DU_{lq}) by the equation:

$$DU_{lq} = 1 - (1.27C_v) \text{ or } DU_{lq} = 1 - 1.27(1 - EU_{stat})$$

The factor k_{lq} = 1.27 equates the statistical uniformity coefficient to a low quarter uniformity equivalent assuming a normal distribution.

Eqn 37 Emitter emission uniformity (EEU_{lq})

$$EEU_{lq} = 1 - 1.27\left(\frac{\sqrt{(Cv_{man})^2 + (\overline{Cv_{defect}})^2}}{(\sqrt{n})}\right)$$

where

EEU_{lq}	is the emitter emission uniformity
Cv_{man}	is the coefficient of emitter manufacturing variation
Cv_{defect}	is the mean coefficient of variation due to blockages, wear and tear determined from emitter tests 1, 3 & 4.
n	is the number of emitters per plant

The factor k_{lq} = 1.27 equates the statistical uniformity coefficient to a low quarter uniformity equivalent assuming a normal distribution.

Eqn 38 Uneven drainage coefficient ($F_{drainage}$)

$$F_{drainage} = 1 - \left(\frac{n_{ER}}{100} \left(\frac{(T_{ER})}{(T_{irrig})} \right) \right)$$

where

$F_{drainage}$	is the effect of unequal system drainage
n_{ER}	is the percentage of emitters that run after system shut down
T_{ER}	is the average time for which those emitters run after system shut down
T_{irrig}	is normal duration of a scheduled irrigation event

Eqn 39 Uneven spacing coefficient ($F_{spacing}$)

$$F_{spacing} = \frac{(D_{Z\min})}{(D_{Zmean})}$$

where

$F_{spacing}$	is the effect of spacing
D_{Zmin}	is the minimum depth applied to a zone
D_{Zmean}	is the mean depth applied to the whole field

Eqn 40 Pressure adjusted emitter flow (Q_{Padj})

$$Q_{Padj} = Q_{Em} \left(\frac{\left(\overline{P_{field}}\right)^x}{(P_{test})^x} \right)$$

Where:

Q_{Padj}	is Pressure adjusted emitter flow
Q_{Em}	is measured emitter flow
P_{field}	is mean pressure determined from whole field pressure tests
P_{test}	is pressure at which block was flow tested
x	emitter discharge exponent

Eqn 41 Emitter defect coefficient of variation (Cv_{defect})

$$Cv_{defect} = \sqrt{(Cv_{QPadj})^2 - (Cv_{man})^2}$$

where

Cv_{defect}	is the effect of emitter blockages, wear and tear
Cv_{QPadj}	is the coefficient of variation of pressure adjusted flows
Cv_{man}	is the manufacturer's coefficient of variation of emitters

NOTE: The Clemmens – Solomon equation (Eqn 27) causes problems here if the measured field uniformity is better than CV_{man} as it would require a square root of a negative number.

Eqn 42 Design Uniformity (EU_{des})

$$EU_{design} = \left[1.0 - \frac{1.27Cv_{man}}{\sqrt{n}}\right]\frac{q_m}{q_a}$$

where

EU_{des}	is design emission uniformity
Cv_{man}	is the manufacturer's coefficient of variation of emitters
n	is the number of emitters per plant
q_m	is the mean low quarter emitter discharge due to the mean low quarter pressure
q_a	is the overall mean emitter discharge

(Keller and Karmeli, 1974: ASAE 405.1)

5.2.1.7 Application calculations

Eqn 43 Mean system application depth (D_{mf})

$$D_{mf} = \frac{Q_m \times T_{irrig}}{A}$$

where

D_{mf}	mean application depth based on system flow rate (mm)
Q_m	system flow rate (L/h)
T_{irrig}	is the duration of an irrigation event (hours)
A	area of the irrigated strip (m2)

Eqn 44 Infiltration depth (drip-micro and long-lateral)

$$D_{\inf} = \frac{Q_{\bar{x}} \times T_{irrig}}{A_{wetted}}$$

where

$Dinf$	is the depth water infiltrates (mm)
Q_x	is the average flow per emitter (L/h)
T_{irrig}	is the duration of an irrigation event (h)
A_{wetted}	is the wetted area per emitter (m^2)

Eqn 45 Equivalent applied depth (drip-micro)

$$Dz_{app} = \frac{Q_{\bar{x}} \times n_e \times T_{irrig}}{A_{plant}}$$

where

Dz_{app}	is the Applied Depth in an given zone, z
Q_x	is the average flow per emitter
N_e	is the number of emitters per plant
T_{irrig}	is the duration of an irrigation event
A_{plant}	is the ground area per plant

Eqn 46 Reference application rate (R_{ir})

$$R_{ir} = \frac{\overline{D}}{T_{irrig}}$$

Where:

R_{ir}	is the reference application rate (Assumed constant)
$\overline{D}$	is mean depth of water from all collectors used in analysis
T_{irrig}	is the duration of an irrigation event

Eqn 47 Instantaneous application rate (R_{it})

(changed from FDIS)

$$R_{it} = \overline{D}_i \left(\frac{V_i}{A_w} \right)$$

Where:

R_{it}	is instantaneous application rate for transect i (mm/hr)
$\overline{D}_i$	is mean application depth applied to strip width at transect i (mm)
A_w	is wetting area of distribution system (m)
V_i	is mean travel speed of the distribution system at transect i (m/h)

Eqn 48 Instantaneous application rates – linear move (R_{il})

$$R_{il} = 3{,}600 \left(\frac{Qm}{L_e \times W} \right)$$

Where:

R_{il}	is the instantaneous application rate (mm/hr)
W	is the wetted width (diameter) of nozzle pattern (m)
Q_m	is the Machine discharge (L/s)
L_e	is the effective length of lateral (m)

The constant 3,600 assumes that the peak application rate is about 4π that of the average application rate if the application rate pattern is elliptically shaped (CPD).

Eqn 49 Instantaneous application rates – centre pivot (R_{ip})

$$R_{ip} = 9{,}170 \left(\frac{Q_f}{r_e^{\,2}} \right) \frac{r}{W}$$

Where:

R_{ip}	is the instantaneous application rate at radius, r (mm/hr)
r	is radial distance from pivot centre to point under study (m)
W	is the wetted width (diameter) of nozzle pattern at r (m)
Q_f	is the discharge for the full irrigated circle (L/s)
r_e	is the effective radius of the full irrigated circle (m)

The constant 9,170 assumes peak application rate is about 4π the average application rate if the application rate pattern is elliptically shaped (CPD).

5.2.1.8 Additional calculations

Eqn 50 Machine speed, (*S*)

$$S_i = 60 \times \left[\frac{D_i}{T_i} \right]$$

where

S_i	is machine travel speed at position, *i* (m/minute)
D_i	is a selected travel distance at position *i* (m)
T_i	is the time taken for machine to move distance D_i (seconds)
60	is constant changing seconds to minutes

Eqn 51 Speed difference for travelling irrigator (*DV_{max}*)

$$Dv_{\max} = \left[\frac{S_{\max} - S_{\min}}{\bar{S}} \right]$$

where

$DV_{\max}$	max deviation in travel speed relative to the mean
S_{max}	maximum machine speed
S_{min}	minimum machine speed
$\bar{S}$	mean machine speed (m/h)

Eqn 52 Hydraulic efficiency (E_{hyd})

$$E_{hydx} = 100 - \left[\frac{(P_{HW} + (EL_{HW} \times 9.81)) - (P_{EI} + (EL_{EI} \times 9.81)}{P_{HW}} \right] \times 100$$

where

E_{hydx}	is hydraulic efficiency (%)
P_{HW}	is pressure after the headworks (kPa)
EL_{HW}	is elevation at headworks (m)
P_{EI}	is pressure at entry to irrigator/distribution system (kPa)
EL_{EI}	is elevation at entry to irrigator/distribution system (m)

Eqn 53 **Headworks efficiency (E_{hw})**

$$E_{HW} = 100 - \left[\frac{P_{PD} - P_{HW}}{P_{PD}} \right] \times 100$$

where

E_{HW} is hydraulic efficiency (%)

P_{PD} is pressure after the pump (kPa)

P_{HW} is pressure after the headworks (kPa)

Eqn 54 **Pumping efficiency (E_{pump})**

$$E_{pump} = \left[\frac{(Q_{sys} \times 60) - (P_{NP} / 9.81}{P_{PD}} \right] \times 100$$

where

E_{pump} is pumping efficiency (%)

Q_{sys} is pumped volume (system flow (from water meter))

P_{np} is nett pump pressure (kPa)

P_{PD} is pressure after the pump (kPa)

Eqn 55 **Theoretical return interval (RI_{the})**

The theoretical return interval is calculated from the readily available water and the crop water use. Crop water use is determined from Peak PET and crop factor.

$$RI_{ther} = \left[\frac{RAW}{(PeakPETxCropFactor} \right]$$

5.2.2 Evaporation from collectors

5.2.2.1 Basis of these guidelines

The guidelines that are established in this Code account for evaporation by adjusting measured volumes from test collectors by relative losses from the control collector(s).

Steps to minimise evaporation losses should be taken as first preference. These include running testing at times of low evaporation such as at night or in the 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).

Evaporation from free water can easily exceed 1mm per hour around midday in summer. If low volumes are collected in wide collectors, a difference in collection time of one hour can generate significant errors.

5.2.2.2 Minimise evaporation influence

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).

5.2.2.3 Exceptions

There is a potential problem estimating evaporation effects when conducting uniformity tests of rotating boom and big gun travelling irrigators. The wetting pattern of such irrigators describes a circle or arc, so collectors placed at the outer limits of the wetted strip width will cease receiving water well before those in the centre.

The time between the outside and inside collectors exiting the wetting area can vary considerably. Adjusting collectors by the method prescribed above will not accurately reflect evaporative effects on caught volume (depth).

The recommendation is to collect and measure caught volumes (depths) in collectors as soon as they are outside the wetting area. This makes evaporative effects negligible, so no adjustment is required.

5.2.2.4 Establish control collectors

If adjusting for evaporation loss, place a control collector (ISO specifies a minimum of three) in a representative location upwind of the test area. At the end of the test period, add the approximate average catch volume of water to the control collector and record the time. After measuring all test collectors, measure the volume in the control collector and record the time.

Measure and record the volume of water in each collector as soon as possible after the collector is no longer within the range of the water pattern. If adjusting for evaporation loss, record the time from when each collector is in range of the water pattern until collector volume is measured (ISO, Cal).

5.2.2.5 Measure collected volumes

Measure and record the volume of water in each collector as soon as possible after the collector is no longer within the range of the water pattern. If adjusting for evaporation loss, record the time from when each collector is in range of the water pattern until collector volume is measured (ISO, Cal).

When all test collectors have been measured, measure the volume in the test collector. If multiple test collectors are used determine the average loss.

5.2.2.6 Accounting for evaporation losses

1. Adjust test collectors

Adjust the test collector volumes to account for evaporation losses.

Assume the evaporation rate from the control collector(s) was constant and determine the volume lost per minute.

Convert the volume lost to an equivalent depth.

Add the calculated loss to the calculated applied depth in each test collector.

Worked example

Assume the test measurement took 50 minutes, and 250 mL of 1000 mL added to the control collector evaporated.

Therefore: 125mL/1000mL = 0.125L/L evaporated in 50 minutes, or
0.125/50 min = 0.0025 L/min

The diameter of the control collector is 250mm.

Therefore: Area of collector mouth = Pi x (250^2/4) mm^2
= 3.142 x 15,625 mm^2
= 49,087 mm^2
= 0.049 m^2

Therefore: Evaporation rate = 0.0025 L/min / 0.049 m^2
= 0.05 mm/min

Assume the first test collector was measured 25 minutes after irrigation stopped, and the measured volume was 300 ml.

Therefore: 0.05 mm/min x 25min = 1.25 mm evaporated

The diameter of the control collector is 250mm.

Therefore: Applied depth = 0.300 L / 0.049 m^2
= 6.1 mm

Adjusted volume accounts for (adds) lost water

Therefore: 6.1 mm + 1.25 mm = 7.35 mm effective applied depth

This calculation must be repeated for each collector, so a prepared computer program is strongly recommended.

5.2.3 Overlapping systems

5.2.3.1 Overlap accounting

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

Translate the out-of-strip data in each collector column (transverse collector line) by a distance equal to the Irrigated strip width (E).

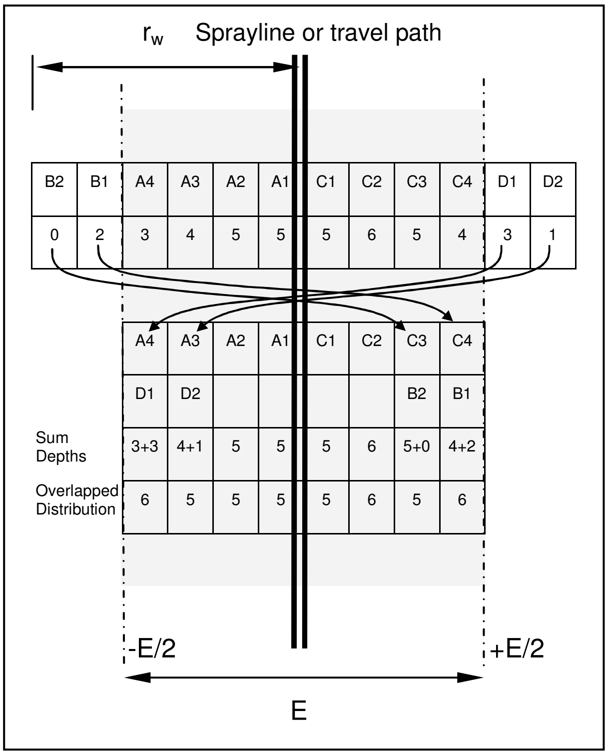

Fig 5.2.3: Translation of out of strip data to wetting strip application depth estimates (From FDIS: 8224/1 2003)

5.2.3.2 Alternate sets

Where alternate sets are used, application depths must be adjusted to account for secondary overlap effects.

The approach taken is to overlay A4 on to C1, A3 on to C2, and A2 on to C3 etc as in

(**Fig 5.2.3** above).

5.2.4 Crop Factors

Crop factors (K_c) for a range of perennial crops grown in New Zealand are presented in Table 5.2.4 1 Tasman Regional Water Study, 2003. These account for an estimated ground cover factor (K_{gc})as well as crop specific factors (K_{crop})

Table 5.2.4 1 Crop factors (K_c) by month

Month	**Apples**	**Kiwifruit**	**Grapes**	**Berries**	**Stonefruit**	**Pasture**
September	0.4	0.4	0.4	0.4	0.4	0.9
	0.4	0.4	0.4	0.4	0.4	0.9
October	0.4	0.5	0.61	0.4	0.4	0.9
	0.5	0.6	0.61	0.6	0.5	0.9
November	0.6	0.8	0.97	0.8	0.6	0.9
	0.7	0.9	0.97	0.9	0.65	0.9
December	0.7	1.0	0.83	1.0	0.7	0.9
	0.9	1.1	0.83	1.1	0.75	0.9
January	1.0	1.1	0.8	0.5	0.8	0.9
	1.0	1.1	0.8	0.5	0.8	0.9
February	1.0	1.1	0.7	0.4	0.8	0.9
	1.0	1.1	0.7	0.4	0.7	0.9
March	0.95	1.1	0.7	0.4	0.6	0.9
	0.9	1.0	0.7	0.4	0.4	0.9
April	0.4	0.8	0.7	0.4	0.4	0.9
	0.4	0.4	0.7	0.4	0.4	0.9
May	0.4	0.4	0.6	0.4	0.4	0.9
	0.4	0.4	0.6	0.4	0.4	0.9
June	0.4	0.4	0.4	0.4	0.4	0.9
	0.4	0.4	0.4	0.4	0.4	0.9
July	0.4	0.4	0.4	0.4	0.4	0.9
	0.4	0.4	0.4	0.4	0.4	0.9
August	0.4	0.4	0.4	0.4	0.4	0.9
	0.4	0.4	0.4	0.4	0.4	0.9

Source: Tasman Regional Water Study – Technical Report Stage 1: Land & Climate Suitability for Irrigated Crops. Prepared for TRWAC by Lincoln Environmental (Report No 4487/1, August 2003)

Table 5.2.4 2 Proportion of potential transpiration from sowing to full ground cover

	Effective Ground Cover, %									
Crop	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Beans	0.2	0.23	0.3	0.4	0.5	0.65	0.75	0.9	1.0	1.07
Peas	0.2	0.25	0.3	0.4	0.5	0.65	0.75	0.85	1.0	1.05
Potatoes	0.1	0.15	0.2	0.3	0.4	0.55	0.65	0.75	0.85	0.9
Corn	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
Lucerne	0.35	0.45	0.6	0.7	0.8	0.9	1.0	1.0	1.0	1.0
Pasture	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Source: Davoren, A. 2002 Planning and monitoring irrigation rotations. Report for LandWISE

5.2.5 Maximum allowable depletion (MAD)

Approximate values for maximum allowable depletion for a range of common crops are presented in (Table 5.2.5)

Table 5.2.5. Maximum allowable depletion MAD for a range of crops on silt loam

Crop	**MAD (% AWC)**
Ryegrass pasture	30-35
Spring barley	60-65
Peas	35-45
Potatoes	30-45
Lucerne	70-75
Onions	30-60
Pipfruit	55-65
Grapes	70-80

Source: Davoren, A. 2002 Planning and monitoring irrigation rotations. Report for LandWISE

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5.3 Equipment specifications

5.3.1 Collectors: Design, dimensions and orientation

5.3.1.1 Meet specifications in adopted standards

Where an audit is conducted according to specifications in any recognised standard, the collectors must meet the specification established in that standard.

5.3.1.2 Collectors for sprayer and sprinkler irrigation

These guidelines apply to collectors (catch cans) used to intercept irrigation water under sprayer or sprinkler irrigation systems where only a part of the flow from one or more sprayers or sprinklers is captured.

1. Basis of these guidelines

The guidelines for collector design and dimensions established in this Code are based specifications for collectors established in ISO 7749-2:1990, and in ISO 11545:2001(E).

Note: These two ISO Standards have different specifications for collectors, and the specifications do not correlate.

2. Minimum requirements for collectors

Ensure that all collectors used for a test are identical and shaped such that water does not splash in or out. Ensure that the lip of the collector is sharp, symmetric and without depressions or deformities. Ensure the entrance diameter (mouth) of the collector is half to one times its height, but not less than 75mm. Ensure that the height of the collector is at least twice the average depth of water collected during the test, but not less than 150mm.

Collectors that are intended for collecting water for transfer to a measuring device will have a sharp edged round opening as described above. They may be cylindrical or conical, with sidewalls inclined to at least 45^{o} from the horizontal.

Other types of collectors may be used, provided that their accuracy is not less than the accuracy of the collectors described above.

To minimise measurement error, testers are encouraged to use collectors that are as large as possible (ISO). A 10 - 20 litre bucket with a mouth opening of 250 – 300mm is generally practical (NZI, Cal).

Note that many buckets have a widened lip/rim, in which case the best estimate for diameter is to measure to the centre of the rim.

Set collectors level, and so their mouth is the same height as, and not affected by, the canopy (Cal, NZI).

3. Minimising error

To minimise measurement error, testers are encouraged to use collectors that are as large as practicable. Collectors used for measuring volumes should be cylindrical (rather than conical) to avoid interpolation errors in reading.

Measuring devices should be cylindrical and graduated with marks at no less than 10% of the volume being measured. Ideally the measuring device capacity will exceed the volume to be measured. This avoids error and time involved in splitting collected volumes into multiple readings.

5.3.1.3 Collectors for micro-sprinkler irrigation

1. Basis of these guidelines

The guidelines for collectors established in this Code apply to sprayers and sprinklers where the entire flow is collected for measurement. There is currently no international specification for this test.

Typically this will be restricted to micro-sprinkler irrigation systems where the water applied by an individual sprayer or sprinkler is directed to part of the root zone of an individual plant. This is likely to be in a mature orchard situation where the tree roots occupy all the area that is wetted by the sprayer or sprinkler.

Special consideration must be given to in-field measurements in orchards where one sprayer or sprinkler is used to apply water to two young plants with small root systems. Careful observation will identify whether plants are receiving applied water.

2. Minimum requirements for collectors

The minimum requirement for collectors is that all water emitted is collected without affecting the flow rate of the sprayer or sprinkler by blocking flow or causing pressure changes. This will involve shrouding the sprayer or sprinkler with a vented cover in such a way that normal operating pressures and flows are maintained.

3. Minimising error

To minimise measurement error, testers must ensure that normal operating pressures and flows are maintained. Either of two alternative approaches may be used: placing a shroud over the sprayer or sprinkler in situ and directing the captured flow to a second vessel for collection (Fig 5.3.1), or placing the sprayer of sprinkler in a container ensuring the sprayer or sprinkler outlet is not flooded and is at the same elevation as in the field.

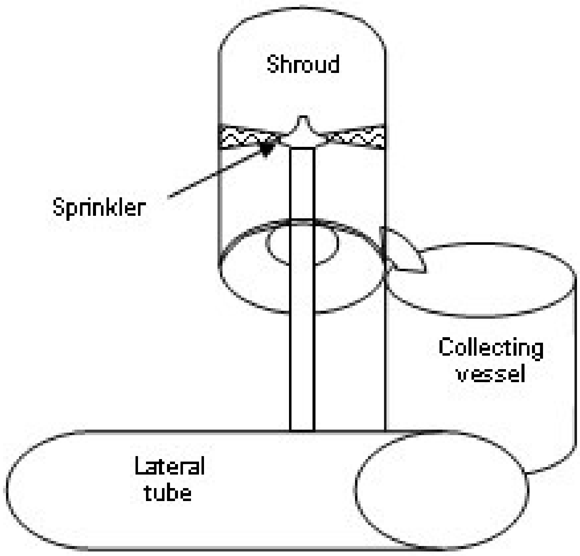

Fig 5.3.1 Shroud for sprayer flow collection

Measuring devices should be cylindrical (rather than conical) and graduated with marks at no less than 10% of the volume being measured to avoid interpolation errors in reading.

5.3.1.4 Collectors for dripline irrigation

1. Basis of these guidelines

The guidelines for collectors established in this Code recognise the specifications for collectors established in ISO 9261:1991(E) *Agricultural irrigation equipment – Emitting pipe systems – Specification and test methods* apply only to new pipe and emitting devices measured in laboratory conditions.

In-field measurements, especially of buried dripline, require special consideration.

2. Minimum requirements for collectors

ISO 9261 specifies only that the emission rates of the emitting-pipe shall be measured with an error not exceeding ± 2% of the actual values.

The system of collection used must capture all the flow from that section of pipe and/or emitters being assessed without affecting the flow rate of the sprayer or sprinkler by blocking flow or causing pressure changes.

3. Minimising error

To minimise measurement error, testers must ensure that all flow is captured and normal operating pressures and flows are maintained. Practically, this can be done by placing stopper rings around the pipe at the end of the section being measured, and a collection tray underneath the pipe or emitter in situ ensuring the outlet is not flooded and is at the same elevation as in the field (Fig 5.3.2). The captured flow should be transferred to a second vessel for measurement.

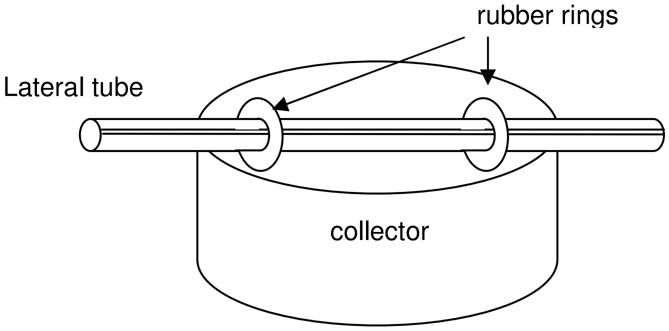

Fig. 5.3.2. Drip-line collector

5.3.1.5 Measuring Devices

Measuring devices should be cylindrical (rather than conical) and graduated with marks at no less than 10% of the volume being measured to avoid interpolation errors in reading.

Standard plastic measuring cylinders of a range of volumes (100 – 2,000 mL) are suitable for field use.

5.3.2 Pressure gauges

5.3.2.1 Meet specifications in adopted standards

Where an audit is conducted according to specifications in any recognised standard, the pressure gauges and sampling methods must meet the specification established in that standard.

5.3.2.2 Gauge specifications

1. Existing accuracy standards

ISO Standards 7749-2:1990, 11545:2001, and 9261:1991 specify that pressure gauges shall have an error not exceeding ± 2% of actual values. ISO 8224/1:1985 *Travelling irrigation machines* establishes that pressure gauges shall have an error of less than ±10 kPa.

For practical purposes, gauges with error of less than ± 2% of actual values should be used.

2. Gauge reading range

The pressure gauge used should have a reading range that is centred on the pressure value being taken.

5.3.2.3 Measurement techniques

A variety of pressure measurement techniques and positions are specified in standards and other guidelines. The critical factor is to ensure the same method is used for all similar measurements in any evaluation exercise.

1. Microirrigation laterals

Unless pressure test points are fitted to a microirrigation system, pressure measurements in the field are made using a pressure gauge with a pitot tube. The pitot is inserted into a hole punched in the lateral tubing, and the pitot directed to face into the flow (**Fig 5.3.3**).

The measurement is made with the lateral in its normal position, and the hole is sealed with a 'goof plug' once the reading is completed.

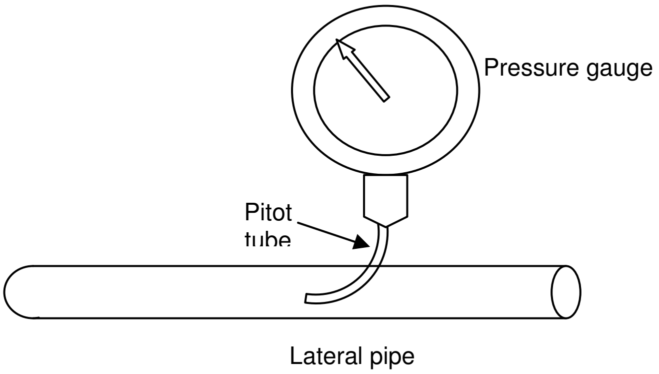

Fig 5.3.3 Pitot tube to measure soft lateral in-line pressure

2. Sprinklers, rotators or multi-outlet sprayers

ISO 7749-2:1990 establishes a procedure for measuring sprinkler pressures (see Fig 5.3.4)

The test pressure shall be measured at the height of the main nozzle of the test sprinkler. The point at which pressure is measured shall be located at least 20cm upstream of the sprinkler so that the pressure measured is not affected by any local variation. No fitting or device which may cause a drop in pressure shall be installed between the point of pressure measurement and the sprinkler.

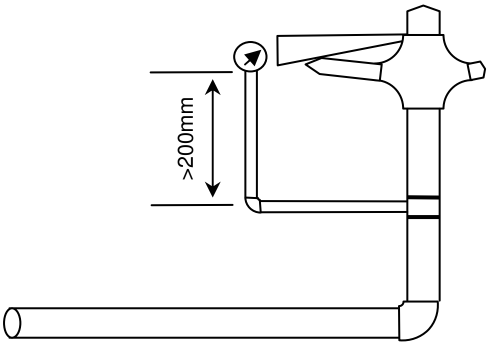

Fig 5.3.4 Measurement of sprinkler pressure from ISO 7749-2: 1990

3. Sprayer or sprinkler orifice

For in-field pressure measurement on existing systems the simplest method is usually to take pressure readings at the nozzle outlet or orifice. This technique may not be possible with some designs, or where the orifice diameter is very small.

A pressure gauge fitted with a pitot is used, with the pitot inlet positioned in the centre of the flow stream just outside the orifice (Fig 5.3.5 Measurement of sprinkler pressure).

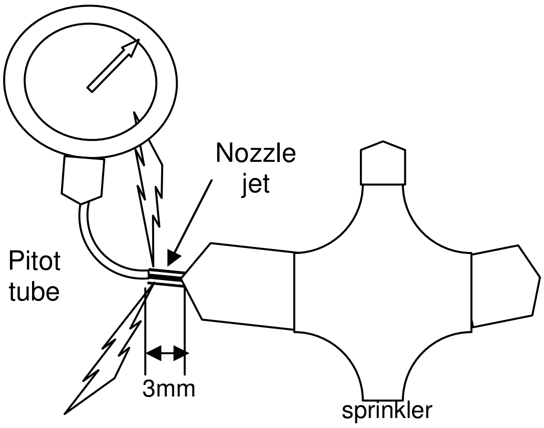

Fig 5.3.5 Measurement of sprinkler pressure

5.3.2.4 In-field sprinkler pressure measurement

It is very difficult to obtain satisfactory pressure measurements from moving irrigators, and from irrigation systems such as centre pivots where very high discharge rates are common.

It is possible to install tees fitted with pressure test points upstream of the sprinkler in many instances. The pressure can then be measured using a gauge fitted with a long flexible hose and pressure test needle.

5.3.3 Flow Meters: range and accuracy

5.3.3.1 Meet specifications in adopted standards

Where an evaluation is conducted according to specifications in any recognised standard, the pressure gauges and sampling methods must meet the specification established in that standard.

In addition, a fitted meter must comply with any regulatory requirements such as those in a Resource Consent.

5.3.3.2 Fitted water meters

The accuracy of flow meters fitted to irrigation systems is dependent on manufacture (quality) installation and maintenance history. Generally in-line flow meters fitted in New Zealand have high accuracies when supplied, generally better than ±5%, so potentially give good results.

However, the accuracy can rapidly deteriorate. If water quality, especially suspended solids or included debris, is poor particular caution should be applied to meter readings. This is also the case if maintenance history is not known or unsatisfactory.

Field checks of meters regularly identify inaccuracy (often in the order of 30%) because of wear, damage or incorrect installation.

Meters should be fitted with a straight length of pipe equal to at least 10 pipe diameters upstream, and another straight length of 5 pipe diameters downstream. This should avoid influence of turbulence effects.

Deliberate sabotage or wear of internal gauge components is difficult to assess without dismantling the meter.

5.3.3.3 Mobile test water meters

A range of external flow metering technologies is available. Care must be taken to install and operate any such device correctly in accordance with manufacturers' instructions.

Many New Zealand water supplies are "too clean" to give accurate readings with externally mounted meters.

5.3.4 Weather Monitoring

Most standards require monitoring of prevailing weather conditions throughout the period of system testing.

The main purpose of weather records during the test period is to assist post-test analyses. This may include identification of possible causes of non-uniformity (wind), or confirmation of measured evaporation rates (temperature and humidity).

5.3.4.1 Wind Speed

Wind effects in particular can greatly affect system performance and should be monitored carefully.

Equipment used to measure wind speed should be accurate to better than ±5%. Many small handheld meters are available with adequate performance.

Many standards specify a maximum wind speed for reliable uniformity evaluations of 3 m/s. If wind speed is greater than this, the system owner should be consulted and made aware of the potential limitations of results from testing.

Wind speed should be recorded at least once every 15 minutes throughout the test period. A logging meter simplifies this task. The average and maximum speeds should be presented in the report.

5.3.4.2 Wind direction

The direction of wind, and any significant variations, occurring during the test period should be recorded. Generally the direction relative to the irrigation system, particularly for system irrigating strips, is of significance.

5.3.4.3 Temperature

The ambient temperature, and the range of temperatures, during the test period should be recoded. Readings should be taken at no more than 15 minute intervals with equipment accurate to ±1 degree Celsius.

5.3.4.4 Humidity

Equipment used to measure relative humidity should allow monitoring to ±5%. A range of small handheld devices are available that meet this specification.

5.3.5 Elevation

System pressure is sensitive to changes in elevation. Systems that operate at very low pressures may be particularly affected by terrain and elevation determination can be critical in identifying factors contributing to non-uniformity.

5.3.5.1 Survey plans or topographical maps

Irrigation system design plans should provide topographical data to a satisfactory resolution. Use such plans if available, and apply some in-field checks to verify accuracy.

Standard topographical maps (eg NZMS 1 1:50,000 series) do not provide enough resolution. They may however be useful in establishing benchmark elevations.

5.3.5.2 Barometric altimeters

In most cases, an accurate barometric altimeter will provide sufficient accuracy. Equipment used should have altitude resolution of 1.0 m or better.

To ensure atmospheric change effects on barometric readings, all elevation readings should be made as quickly as possible, and the survey should be ‘closed’ by returning to the start point and retaking an elevation (altitude) reading. Variation can be accommodated using standard survey practise, adjusting intermediate readings assuming change was constant.

For ease of reading, use a pole of known length to set the barometer at a constant height above ground level when taking measurements. (Take care to record correct relative levels, if some elevations are determined at above ground locations.)

5.3.5.3 Benchmark elevation

It is not necessary to present elevations as metres altitude about mean sea level (m ASL). Reduced levels relative to a benchmark established on site are sufficient.

Suitable benchmarks will have a clearly defined point of measurement. They will be stable and enable repeated measurements, even at a later date. Examples include a defined point on a solid concrete pad (pump foundation) or similar.

5.3.6 Equipment lists for field work

Misc Equipment
Road map
Farm location / physical address
Contact details
Contact phone number

Data collection sheets
Field book
Pens, pencils
Cell phone
Camera

Magnetic compass – identify North etc
Angle finder
Wind speed meter
Thermometer / Humidity meter
Altimeter
Stop watch

Shovel
Soil probe / auger
Thread tape
Pouch – to hold tools, misc items
Nylon stockings – to sieve flushing water

Clothing
Gumboots
Parka
Overtrousers
Long rubber gloves
Towel
Change of clothes

Misc Tools
Vice grips
Spanner – 20 cm adjustable
Open end spanner set
Wrench – 35 cm adjustable
Pliers – to insert goof plugs
Secateurs
Knife snap blade – cut emitters, drippers
Wire cutters

Length Measurement
100 m fibre tape measure
50 m fibre tape
5 m steel tape
Measuring wheel
Fibre glass poles 1.5 m – to mark speed test runs

Pressure Measurements
Pressure Gauges
  0 – 250 kPa
  0 – 400 kPa
  0 – 1000 kPa
Spare threaded pressure test points
Flexible hose extension – to connect to gauges
Pressure test needles – to connect to gauges
Pitot tubes – to connect to gauges

Drip-micro
Pre-made pressure test points (Tee'd to insert in thin wall drip-line)
Clamps – to close off lateral tubing
Lateral punch – to allow pitot insertion
Goof plugs – to repair holes

Pivot/linear
Threaded tee pressure test points – between dropper and pressure regulator
Bayonet pressure test point – between pressure reg & spray head (Nelson)

Flow Measurement
Measuring cylinders (depend on collector size)
  100 mL
  250 mL
  1,000 mL
  2,000 mL
Measuring jug
  5 L

Drip-micro
Buckets x 30 10L – for sprinkler flow collection
PVC pipe 40mm x 30 pieces (20cm long) – to collect sprinkler flow to bucket
Sprinkler shroud – for sprinklers that are fixed in place
Plastic containers x 30 0.5 - 2 L – for dripper flow collection
Jiffy clips – attached to lateral to prevent dribbling past collector
Other systems
Container of known volume (~ 20L)
Shroud and pipe or hose – to divert sprinkler water to container
Flexible hose 25 – 30 mm 1 m long – to divert sprinkler flow to large container
Buckets x 100 10L – for sprinkler flow collection
Clothes pegs – to stop sprinkler movement

5.4 Reporting format

5.4.1 System layout

Provide a sketch of the irrigation area with North at the top of the page.

Identify water supply and mainline locations, access track, hydrants and any segment excluded from irrigation.

Identify the area(s) watered outside the target area.

Identify the location of sprinklers used in testing, and the wind direction during the test.

Identify the location of the traveller at the start and end of the strip, and the wind direction during the test.

5.4.2 Ground profiles

If the irrigated area contains significant elevation variation, provide a diagram and mark locations of ground profiles measured. Present scale sketches of ground profiles with distance and reduced levels in metres.

5.4.3 Test design

Present a plan showing the location of critical test elements as below:

5.4.3.1 Drip-micro

- Pressure test point locations
- Flow test locations

5.4.3.2 Spraylines / multiple spraylines

- Sprayline position in field
- Grid test location
- Collector placement
- Irrigation strip width
- Wetted radii and locations measured
- Identify wind direction during testing

5.4.3.3 Travellers

- Delivery tube laid position
- Transverse test line locations
- Collector placement
- Irrigation strip width
- Wetted radii and locations measured
- Gun sector angle if relevant
- Wind direction during testing for each transverse line.

5.4.3.4 Lateral moves

- Lateral position in field
- Wetted length
- Lateral uniformity test position
- Longitudinal uniformity test position
- Collector placement
- Wind direction during each test

5.4.3.5 Centre pivots

- Pivot lateral position in field
- Wetted radii
- Radial uniformity test position
- Circular uniformity test position
- Collector placement
- Wind direction during each test

5.4.4 General observations

5.4.4.1 Surface ponding

Note any observed surface ponding

Identify implications of soil water ponding or runoff on actual distribution uniformity

5.4.4.2 Application rates

Present calculated instantaneous application rates.

Identify implications of calculated application rates versus estimated soil infiltration rate

5.4.5 Uniformity

5.4.5.1 Applied depth graph

Present a graph or graphs of collector volumes (corrected for evaporation) along each transverse line. Use shading to distinguish between collector rows.

Present a graph or graphs of applied depths (corrected for evaporation and for overlap) across the irrigated strip width at each transverse line. Use shading to distinguish between collector rows.

5.4.5.2 Distribution uniformity

State the method used to determine uniformity, present the result and give an interpretation based on expectations for the type of system.

Present low quarter Distribution Uniformity (DU_{lq}) as a decimal. Do not present it as a percentage.

For example:

$\text{Lateral } DU_{lq} = 0.83$

Interpretation: This is considered “good” for a linear move irrigator on level ground.

5.4.6 Causes of Non-Uniformity

Identify the contribution to non-uniformity that can be attributed to key causes.

5.4.6.1 Inappropriate strip width

From transverse line and overlap calculations, determine the optimum strip width for highest distribution uniformity at the prevailing conditions and machine settings tested.

5.4.6.2 Wind effects

From transverse line and overlap calculations, determine the effect of wind on distribution patterns if possible.

5.4.6.3 Incorrect components

Report any components that do not meet specifications. Note number and proportion of sprinklers or other components represented.

5.4.6.4 Boom distribution systems

Compare the result of the discharge (sprinkler) and collector distribution uniformity results.

For example:

1. Low quarter discharge uniformity was calculated based on measurements from 16 sprinklers.

   $DU_d = 0.65$

Interpretation: This is considered ‘poor’ for a travelling irrigator fitted with a boom distribution system.

Report possible interference if sprayers not horizontally staggered.

Report on nature of wear, damage or blockage, number and proportion of instances, and any possible causes.

Present an overall interpretation:

5.4.6.5 Pressure

Present pressure measurements made at headworks, hydrants and the machine.

Note range of elevations identified in the field including minimum and maximum variations from a mean or mode elevation.

5.4.6.6 Application rates

Present the calculated instantaneous application rate and the assessed infiltration rate of the soil.

Interpret the result, for example:

The soil is a clay loam with signs of compaction. The calculated application rate of 60mm/hr is high for this soil type.

Field observations found ponding and minor runoff under the wetting area. This indicates excessive application rates and redistribution of water at the soil surface. This will reduce the actual distribution uniformity.

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5.5 References

5.5.1 Related codes and standards

International Organisation for Standardisation (ISO)

ISO 7749-2: 1990 *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 8224/1 – 1985 *Traveller irrigation machines – Part 1: Laboratory and field test methods*

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

ISO 9261: 1991 *Agricultural irrigation equipment – Emitting-pipe systems – Specifications and test methods*

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 14050*:* 2002 *Environmental management – Vocabulary*

American Association of Agricultural Engineers (ASAE)

ANSI/ASAE S436.1 DEC01 Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles (ANSI)

ASAE EP405.1:2001 Design and installation of microirrigation systems

ASAE EP 458: 1995 Field evaluation of microirrigation systems [Withdrawn]

Other

ITRC Irrigation Evaluation: Drip micro 2000 [de facto standard]

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5.5.2 Technical References

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Goodier, C. and Bloomer, D. 2004. *IRRIG8 Software for Irrigation Evaluation*. (Support software for evaluations conducted according to guidelines established in this Code of Practice.

New, L. and G. Fipps. 2002. *Center Pivot Irrigation.* Bulletin B-6096. 4.00. Texas Agricultural Extension Service. The Texas A&M University System. via internet: http://amarillo.tamu.edu/amaweb/Programs/EnviroSys-NatRes/IrrigaWtrQlty/publications/B-6096-CtrPivIrri.pdf

Rout, R. (2004) *Key Performance Indicators for Irrigation Design.* Irrigation New Zealand (unpublished draft)

Smajstrla, A.G., B.J. Boman, D.Z. Haman, D.J.Pitts, and F.S.Zazueta. 1998. *Field evaluation of microirrigation water application uniformity.* Bulletin 265, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Sparrow, D. and M. Skewes. 1998. *Irr-E-Pack: Irrigation Evaluation Package, User Manual.* Primary Industries and Resources, SA. Murray Darling Basin Commission.