Irrigation
management manual

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Training manual

Dairy & Fodder Water for Profit

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Preface

The Rural Water Use Efficiency (RWUE) project has been funded by the Queensland Government since 1999, with industry bodies responsible for managing their individual projects. The Dairy and Fodder Water for Profit project is managed by the Queensland Dairy Farmers’ Organisation and supported by DEEDI. The project team has sought to improve irrigation systems and management practices of both Dairy and Fodder farmers throughout the State.

Irrigation practices have changed significantly over the duration of the project, the catalyst for this has been the Financial Assistance program that has enable producers to purchase improved irrigation hardware and benefit from the Team’s irrigation evaluations that have provided data on the actual performance of systems.

When the project commenced the majority of irrigation systems were of a high pressure nature and there was generally little understanding of the benefits of improved irrigation systems. As new hardware was installed the Team and producers started to realise the potential of low and medium pressure systems particularly. Producers have made savings of over 60% with the new equipment and many have installed more than one area of improved irrigation since realising the benefits.

The consistent message that the RWUE team has delivered for over a decade is that the irrigation system alone does not make for improved efficiencies; it is in fact competent management of the whole farming system that realises the largest gains. With an improved irrigation system, correct fertiliser applications, grazing management, scheduling etc. producers are able to maximise gains across the business. There are many examples of profitable changes in practice in both the Dairy and Fodder industries that have stemmed from the involvement in the RWUE programs since the late nineties.

This book highlights some of the most important areas when considering irrigation management. Soils, irrigation systems, pumps, scheduling and economics are all discussed. The important topics of forage and grazing management are not included in this publication, they are however essential in achieving improved irrigation efficiencies and information is available through other DEEDI resources.
Module 1 - Soils

Checking soil type

Purpose
Provide information on the main soils used for subtropical dairying.
There are four commonly occurring soil groupings used for subtropical dairying.

Clay soils
Black cracking clays

Also known as black earths, heavy river-flat soil or Black Vertosols.
A deep, dark, fertile soil occurring on alluvial plains.
Examples include the main cropping soils of the Darling Downs; heavy soils of the Richmond River; flats along the Logan and Albert Rivers; flats along Lockyer, Cressbrook and Warrill Creeks; and the less fertile, flood prone cracking clays in the South Burnett.
Grey cracking clays

Also known as grey clay, grey scrub and brigalow soils or *Grey Vertosols*. A fertile cropping and grazing soil, from grey to almost black, often with abundant stones. Depth variable. Found in most subtropical dairy regions. Occurs as alluvial flats or plateau soils.

Red clays

Also known as red scrub, red basalt, red loam, and chocolate soils or *Ferrosoils and Krasnozems*. An important, deep, friable, highly permeable and fertile soil. Examples include the red soils of the Atherton Tablelands, Kingaroy and Maleny. They shouldn't be confused with some infertile red soils, such as Red Earths.
Deep prairie soils

Also known as loamy creek flat and dark loam soils or Dermosols and Chernozems.

A premium dairy soil that is deep and free draining with little change in texture at depth. It is an alluvial loam found on creek flats throughout most subtropical dairy regions.

Red earth soils

Also known as red loam soils or Kandosols.

Found in most subtropical dairy areas the soil is deep, porous and friable, but has weakly developed structure and low fertility. Soil texture changes little at depth.
Loam soils
Texture contrast
Brown or Red duplex soils

Also known as red-brown earths or Chromosols, Red Podzolics and Brown Podzolics.
These soils have a marked change in texture between the topsoil and the subsoil, often due to higher clay content in the subsoil. They are mostly hard setting and have low fertility. Many subtropical dairying areas have these soil types on hills and slopes above creek or river flats.

Sodic loam soils

Also known as Sodosols, Solodics and Solodised Solonetz.
A problem soil requiring careful management. These soils have a sharp boundary between the loamy topsoil and hard clay subsoil, usually with a prominent bleached layer between. The subsoil is prone to tunnel erosion while the surface can be hard setting.
Checking soil health

Purpose:

- Provide a guide and some easy tools for checking soil health
- Highlight management practices for maintaining soil health

A healthy soil is a combination of good soil structure, organic matter content, biological activity and chemical elements. This maximises the capability of the soil to support plant growth.

The focus when growing pastures and crops is often on just the main plant nutrient requirements, like nitrogen and phosphorus. There are also chemical elements that reduce soil health, such as sodium (Na), aluminium (Al) and chloride (Cl). The bottom-line for efficient and sustainable feed production is to keep the right balance between all of the soil’s organic, structural and chemical elements.

Dairy farming greatly impacts on the soil organic, structural and chemical balance through:

- Intensive grazing and cropping practices required for high-yielding forages
- Removal of large quantities of nutrients from the soil due to these high yields
- Nutrients being unevenly distributed around the farm through cow movement and removal of plant products from paddocks

This step in the program looks at the following soil properties that have a major impact on soil health:

- Soil Structure
- Organic Matter & Biological Activity
- Soil Chemical Degradation
- Erosion

**Soil structure**

Soils with good structure have enough spaces or pores to help air and water movement. Any soils that dry like concrete or become a boggy mess when wet are unable to support cost-effective production. Aspects of dairy farming that adversely affect soil structure include intensive grazing and cultivation, especially when too wet, and depletion of soil organic matter.

The particular soil structural problems that can develop are:

- Soil dispersion or structural breakdown in the topsoil in the form of crusting
- Surface-sealing or powdering
- Soil compacted layers, usually about 20 - 40cm down the soil profile

**Checking soil structure**

Check for a decline in soil structure where:

- Paddocks are regularly cultivated and cropped
- Cows have grazed on wet soils, especially if pugging has occurred
- Pastures have been grazed for greater than 10 years without being renovated
**Improving soil structure**

Practices that improve structure aim to increase organic matter, avoid over-cultivation and soil compaction, and break-up compacted soil layers.

Improve soil structure by:

- Reducing cultivation through minimum or zero tillage and by growing perennial pastures
- Delaying cultivation when the soil is too wet to avoid compaction and plough pans
- Using pasture leys in cropped areas
- Topping pastures to help recycle plant material
- Applying soil conditioners, such as animal manures and gypsum
- Using grazing practices that avoid soil compaction from animal 'pugging'
- Restricting heavy animal and machinery traffic to laneways and using controlled traffic practices
- Encouraging natural cracking in self-mulching soils

**Methods & Indicators for checking soil structure**

Some easy methods for checking soil structure and sodicity include:

- ‘Look & Feel’ of cultivated soil (simple and quick)
- Structure & sodicity tests (simple, yearly tests)
- Digging a hole

**‘Look & Feel’ of cultivated soil**

A quick way to judge the condition of soil in cultivated paddocks is to notice how the soil looks and feels when it’s ready for planting:

- A cultivated paddock when walked on should feel ‘springy’, not hard and flat
- Soil lumps, also called aggregates or peds, should look intact and not ‘washed-down’ or ‘melted’ after rain (except with cracking clays)
- Small, white sand grains on the soil surface indicate ‘melted’ aggregates.
- No patches of surface crusting should be seen when the soil has dried

**Well-structured topsoil**

The soil is friable and feels crumbly

Soil has worked-down to a good seedbed that provides ideal seed to soil contact. The aggregate sizes vary but they are stable when wet and don’t melt. Pore space is ample, allowing good air-flow and drainage. Roots are prolific.
Compacted topsoil

The soil feels hard and sharp

Soil is hard and cloddy. Dry aggregates require a lot of pressure to break by hand and are difficult to work down. Pore space is low, restricting air-flow, drainage, and root penetration. This is a poor environment for seed germination or plant growth.

Good sub-soil

This clay sub-soil is well structured. Clods break down with little pressure. Roots can proliferate if they reached this depth (30-40cm).

Structure & sodicity tests
Saucer test (structure)

This test determines whether soil aggregates will retain their strength when wetted and is useful for checking the condition of surface soil after cropping or under older pastures. Poor structure and low organic matter is indicated if soil aggregates break down or disperse (melt) easily when placed in water.
Dispersion test (sodicity)

A similar procedure, using several surface soil aggregates and rainwater, provides a check for sodicity. For this test, the saucer is left undisturbed and the water around the aggregates checked for cloudiness after 5 minutes and 2 hours. The pictures below show the cloudiness that occurs with soils that are sodic. The test can also be applied to the sub-soil if sodicity is suspected deeper in the soil.
Soil probe

A soil probe is simply a metal rod with a cone or pointed tip at the end and it is pushed approximately 30-40cm into a wetted soil profile to test for compaction. The probe may be a modified electric fence post that will allow testing to be done when shifting the fence. The user needs to develop a ‘feel’ for well-structured soil and also be able to sense the difference between a compacted and dry soil layer. A benchmark for good structure can be obtained by testing under fence lines adjacent to the paddock where cultivation and compaction hasn’t occurred.

There is some disagreement amongst soil ‘experts’ whether farmers can develop this feel, but by trial and error and comparisons with other methods such as digging down to check suspect compacted layers, the probe provides a quick and cheap testing tool.

Spade test

This involves examining a relatively intact spade-full of soil. The first step is to locate an undisturbed area of the soil type to determine its natural soil structure. Examples of undisturbed areas are beneath fence lines, along a tree line or a long-term pasture that has had little grazing. The next step involves carefully removing and retaining an intact 10 or 20 cm depth of soil on the spade face, gently breaking it apart by hand, and taking notes on what the natural structure looks like (or a photograph). These observations can then be compared with spade excavations and observations in the paddock where a structure problem is suspected. There is rarely a need to dig deeper than 30-40cm to detect the main structural problems.
**Digging a hole**

Once every few years it can be useful to check most of the soil profile within intensively cropped or grazed paddocks by digging a 60-90 cm deep hole. This takes time and patience but gives insight into the soil’s characteristics and any major changes that may be occurring.

**Organic matter & biological activity**

Decaying organic matter is the life-blood of a productive soil. It plays a crucial role in maintaining and improving soil structure, storing and recycling plant nutrients, and controlling changes in pH. Adequate organic matter and its’ associated biological activity are vital for high pasture and crop production.

The amount of organic matter in the soil depends on the quantity added each year, the rate of decay, and the type of soil. Over an extended period, the organisms in the soil convert fresh organic matter into humus, a relatively stable material. Humus is important in improving soil structure and in providing a very large surface for holding nutrients until required by plants. Humus levels can be built up slowly, but also can be lost quickly through erosion and cultivation.

The two aspects of dairy farming that impact most upon soil organic matter and biological activity are:

- Cultivation, especially full seedbed preparation
- Nutrient and organic matter redistribution on-farm and removal in farm products

**Checking organic matter and biological activity**

Ways to check include:

- Soil tests for organic carbon; relatively easy, although usefulness depends on how often tests are done and consistency of sampling technique
- Observing the rate of organic matter breakdown in the paddock, such as after pasture topping and spreading manure; relatively easy but depends on local conditions and experience
- Direct measures of biological activity; methods vary greatly in time required, expense and accuracy

**Improving organic matter and biological activity**

Improvements can be made by:

- Monitoring organic matter in cultivated paddocks
- Using crop/pasture rotations or manures and other conditioners where levels of organic matter are low
- Maintaining activity of soil organisms, such as worms and dung beetles

**Organic production and biodynamics**

There are viable dairy farms that are completely organically based or biodynamic and, although their production is lower per hectare, so is their cost. It takes a large change in management knowledge and style to convert to organic farming. Organic and biodynamic producer organisations can be contacted for further information.

**Soil chemical degradation**

Important soil health or degradation problems caused by chemical imbalances are:

- Acidification
Acidification occurs widely in the subtropics, with salinity and sodicity being more localised and varying in importance between regions.

**Acidification**

Soils acidify naturally as they weather over long periods of time. However, agricultural practices can greatly accelerate the process resulting in soils quickly becoming sufficiently acid to limit plant growth. Acidification can reduce nutrient uptake, cause aluminium and manganese toxicity, and change soil biological activity. Modifying farming practices and applying and incorporating lime or dolomite (which also supplies magnesium) is the only practical way to minimise acidification.

- Acidification is a widespread soil degradation problem on sub-tropical dairy farms and should be given a high priority when managing soils
- An acidifying sub-surface layer is very serious and must be prevented as it is below the soil surface where lime can be easily incorporated

The potential for greatest acidification will be on those farms:

- Located on naturally acidic soils
- Located in high rainfall regions
- Growing a high proportion of pasture or crop legumes
- Using high levels of ammonium-based nitrogen fertiliser

**Important to know**

Nitrogen fertilisers when used inappropriately will acidify soils. Regular soil monitoring and applications of calcium ameliorants (lime) along with avoiding excessive leaching of nitrates will mitigate this problem.

**Minimise acidification by better soil monitoring and management:**

**Monitoring**

- Test surface (0-10cm) soil pH at least once every three years; or more often for irrigated, intensively cropped and sandy soils
- Check for sub-surface acidity below 15 cm

**Management**

- Commence a regular liming program based on lime requirement soil tests
- Lime sandy soils more frequently than clay soils but at lower rates
- Consider the acidifying effect of nitrogen fertilisers, particularly ammonium-based fertilisers
- Minimise nitrogen leaching by using smaller and more frequent applications of nitrogen and irrigation, particularly on free-draining soils
- Fertilise in accordance with pasture nutrient demand
- Grow deep-rooted grasses with legumes to "sop up" excess nitrogen.
- Return manure (alkaline) back to paddocks and rotate night paddocks

**Salinity**

Well-managed farming systems based on perennial pastures and annual forage crops are unlikely to lead to increased salinity. However, the potential for salinity in the soil profile will be increased where:
- Water in the soil regularly drains beyond the root zone of pastures or crops
- Land is unnecessarily fallowed during summer

Reduce soil salinity risks by avoiding:
- Over-watering, particularly with shallow rooted plants like ryegrass
- Long or unnecessary fallow periods over summer, particularly in high rainfall areas
- Use of poor quality irrigation water

**Sodicity**

This degraded soil condition is caused by excessive exchangeable sodium in the soil with a symptom being a crusted or hard-setting surface due to dispersion of soil particles. Soil dispersion continues to increase as the proportion of sodium increases relative to other exchangeable cations (potassium, calcium and magnesium). Soils are considered to develop hard-setting characteristics and become sodic once sodium comprises more than 6% of the total exchangeable cations.

Soil structure can be improved by applying a source of calcium, such as gypsum. Permanent restoration often requires a considerable quantity of gypsum up to 25t/ha. Because gypsum also acts as an electrolyte the water conductivity of surface-crusted soils may be improved by only 3-5t/ha. A saucer dispersion test can simply identify gypsum-responsive soils.

**Erosion**

Water erosion is a potential hazard on all soils in the northern dairy region. Soils most at risk will be those without sufficient cover during the summer rainfall period, such as cultivated soils and heavily grazed hillsides and gullies. In general, erosion risk will be:
- Lowest with perennial pastures
- Highest with fully cultivated land

Maintaining good ground cover is the key to minimising the potential for erosion.

Reduce erosion risk by:
- Using minimum or zero tillage for annual crops and grasses
- Managing cropping systems to maintain surface cover
- Avoiding long or unnecessary fallow periods over summer, particularly in high rainfall areas
- Avoiding cultivation during periods of high rainfall risk
- Not cultivating steep slopes

Wind erosion is normally restricted to sandy soils but may affect other soils in drought.

**Water quality and salinity**

The presence of soluble salt, either in irrigation water or in the soil solution bathing plant roots, affects crop growth. The most common visual symptom is slower and more stunted growth or no growth at all on very saline areas. A darker green colour as well as greater leaf succulence may be evident. However, in most cases, yield will be the only evident response to indicate salinity, in fact dry matter production may be less affected than yield. Woody species tend to show more leaf damage such as leaf burn and even defoliation. Leaf symptoms
Irrigation management soils

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Notes

Irrigation management soils

Important aspects of irrigation salinity are:

- How suitable is the irrigation water for a particular soil and crop?
- What management practices can be used to minimise salinity, and are there any adverse consequences associated with a particular set of circumstances?

Irrigation water quality assessment

Assessment of the suitability of a water for irrigation requires prediction of the equilibrium soil salinity and sodicity in the soil profile under irrigation. The suitability of a particular water can then be assessed in relation to plant salt tolerance and soil structural stability. The successful, long term use of any irrigation water will depend more on such factors as drainage, rainfall, leaching, salt tolerance of crops, and irrigation and soil management practices than upon water quality itself.

Management options for saline irrigation water

Accurate irrigation water quality assessment is the best preventive measure to reduce salinity effects since a water is matched to the soil properties and crops. However, a number of management alternatives are available to minimise the effects of marginal-quality irrigation waters on soils and crops.

Some management strategies include:

- Changing the frequency of irrigation
- Duration and method of irrigation
- Judicious timing of leaching irrigations
- Mixing of irrigation water supplies
- Cultural practices, including soil amendments

On heavy clay soils, it is often the soil properties which limit the effectiveness of any water management due to their low drainage rate. Coarser-textured soils are more amenable to management alternatives.

Frequent irrigation

More frequent irrigation gives reduced plant water stress, less concentration of the soil solution and, sometimes, greater leaching. It is suitable where irrigation water is available on demand, but requires good drainage. The cost of irrigation may also be increased.

Recent research indicates that the extent leaching can be increased by frequency of irrigation is not large, as excess water tends to be used in evapotranspiration. That is, leaching tends to be self-compensating.

Leaching irrigations

Where leaching is used to control salinity, there are two available options:

- Maintain salt balance throughout the season by applying extra water for leaching irrigation. This control is effective in soils with good drainage where there are no high water tables
- Allow salt to accumulate during the growing season except for specific leaching irrigations, that is, apply extra water every ‘x’ irrigations. This control gives more efficient water use but may cause some yield loss from salt accumulation. Leaching in small, controlled amounts is more efficient than continuous ponding, except for slowly permeable soils.
where continuous ponding is more efficient for salt removal. Timing of leaching irrigations depends on crop salt tolerance and water salinity

- Flood irrigation gives even application but can be wasteful of water, particularly if high-frequency irrigations are required
- Sprinkler irrigation gives good control and maximum flexibility. However, it can cause leaf damage (burn) and salt precipitation on leaves and some water is lost through evaporation increasing the water salinity. Night sprinkling gives less evaporation and less leaf burn

**Crop selection**

Varying the crop can prevent salt accumulation at the same depth in the root zone.

**Methods of irrigation**

The method of irrigation used can affect salt accumulation:

- Trickle irrigation is efficient but causes salt build-up in the surface and edge of wetted areas
- Furrow irrigation gives salt accumulation in adjacent rows through capillary rise and evaporation, therefore planting in the furrow or on the side of larger hills will reduce salt concentration

**Mix water supplies**

Mixing water supplies can reduce salinity hazard if good water is also available but it is generally not as good a use of resources as:

- Alternate irrigation with good water, when available. This will maintain a lower salt balance, provided sodicity is not a problem
- Alternate salt-tolerant and salt-sensitive crops with different irrigation waters. This latter option is preferred where good water is also available

**Mixing water supplies**

Sodic irrigation waters generally result in soil dispersion with consequent soil surface sealing, crusting, erosion, poor water entry and poor seedbeds.

**Gypsum**

Gypsum is increasingly being used as a soil amendment to improve the structure of surface soils and to alleviate some of the adverse effects of high-sodicity waters and those with residual alkali (sodium carbonate). Gypsum improves soil structure by increasing flocculation of clay particles through increased electrolyte concentration and by exchange of calcium for sodium on the exchange complex.
Module 2 - Irrigation systems

Outcomes

Having completed this session you will have knowledge on:

- Application rates and distribution uniformity
- Irrigation hardware
- Pump performance

To identify changes that have the most impact on profitability from irrigation it is important to work through a logical progression of issues. These issues are presented under a strategic and operational framework.

**Strategic issues**

- What are the characteristics of your water supply? This includes amount, reliability, cost, quality etc. Do you have control over any of these factors and do you understand how they will impact on your irrigation management?
- Irrigation systems design. Is it cost effective to modify or expand your irrigation system? What is the maximum application rate? (mm applied/days of rotation)
- What are the best crops to grow with the available water and your irrigation system?
- Soil management. How are you managing your soil to maintain or improve quality and prevent erosion?
- What is the climatic environment of your farm? This includes rainfall patterns, evaporation characteristics etc.

**Operational issues**

- Irrigation system. Have you measured and benchmarked pump efficiency, running costs ($/ML), friction losses and leaks in mains, application amount (mm) of the system, application rate (mm/hr) of the system and distribution uniformity (DU%)?
- Irrigation scheduling. How do you manage when and how much irrigation to apply? Are you maximising rainfall events? What is your strategy for windy days or very high evaporation days?
- Integration into whole farm management. Are you managing fertiliser applications, weeds and pasture utilisation to maximise irrigation productivity? Is cow nutrition and genetics maximising pasture inputs?

**Strategic issues**

**Water supply**

A useful starting point for managing irrigation is to establish your total ML allocation and ML/ha available. This will determine whether you are able to fully irrigate or supplementary irrigate your crop or pasture.

The water quality will affect the types of crops that can be successfully irrigated and the irrigation management strategy employed. Testing the water source is essential.

**Irrigation systems design**

When exploring, upgrading or replacing an irrigation system you need to consider:
Irrigation systems

- The ability of the system to provide the crops water requirements
- The capital cost and the ability of the enterprise to be able to make a return on the investment
- The change in labour requirements
- The change in running and maintenance costs
- The flexibility of the system to allow response to changes in commodity prices

The Dairying Better ‘n’ Better CD is a computer based assistance package that consists of numerous irrigation and environmental calculators and advice sheets.

Soil management

Soil with good structure will allow water to freely infiltrate through soil pores. Organic matter content, cultivation practices and compaction, especially when grazing on wet soils, will affect soil structure.

The ability of plants to convert soil water to dry matter production is directly related to the nutritional status of the soil. Well-managed soils will grow up to three times the dry matter production with the same irrigation inputs, as poorly managed soils.

Irrigation systems that emit a large droplet size can cause surface sealing in certain soils, which can reduce infiltration rates.

Climate

Historical rainfall and evaporation figures provide a useful basis for determining crop water requirement and the design specifications of an irrigation system. They can also provide an indication of the risk associated with growing seasonal crops and pasture.

Operational issues

Irrigation system

Because irrigation systems are regularly used on farms it can be difficult to detect small problems. A seasonal check to ensure systems are working to their capacity makes good business sense. The RWUE team has developed a systems check process that quantifies:

- Operating pressure
- Pump efficiency
- Pumping costs
- Application amount
- Distribution uniformity

Irrigation scheduling

Deciding when to start irrigating and how much to apply are the most regular decisions facing the irrigation manager. Knowing how much to apply requires knowledge of the rooting depth of the crop, water-holding capacity of the soil and distribution uniformity of the irrigation system. Knowing when to start irrigating requires knowledge of how much water is being used by the crop.

This information can be provided by indirect means such as applying a crop factor to evaporation rates or direct means of measuring actual soil moisture content. The RWUE team has evaluated a wide range of new scheduling tools in a commercial situation.
**Whole farm management**

On-farm trials have show a three-fold difference in milk produced per ML of well-managed irrigation. This was due to effective use of nitrogen so more grass was grown; better utilisation of available grass and correct supplementary feeding to maximise conversion of grass to milk. These trials demonstrated that understanding and managing irrigation is only part of the answer to profitable irrigation. It needs to be done within the context of a well-managed farm.

**Remember**

Rain is a scarce resource and it is free so utilising it fully is important.

- Look after the paddocks and soil structure for infiltration
- Don’t irrigate too soon after rain
- Irrigating during rain can cost you money as you may end up over-irrigating
- Minimise the effect of evaporation by maintaining some ground cover

**Water application rate and amount**

Knowing the application rate (mm per hour) and the amount of water (mm per irrigation) delivered by your irrigator is important for:

- Determining whether your irrigation system is capable of meeting crop or pasture water needs
- Working out the number of irrigation shifts and time needed to cover the area being irrigated, and irrigation schedules
- Ensuring your irrigator is efficient and performing according to the manufacturer’s specifications

By knowing the application rate of your irrigator and the crop water needs (amount required) you can work out the time for each shift. For example, if the irrigator applies 3 mm per hour and the crop needs 30 mm, it will take 10 hours to apply this water over the area covered by the shift. Once you know how many shifts it takes to cover the area to be irrigated, you can work out whether the irrigator can meet your crop water needs in the most timely and productive way.

Matching water application to crop or pasture needs is vital for efficient water use and feed production. Operator experience and scheduling tools can help in matching irrigation to the water need of the crop or pasture.

Better operators produce 3000 kg dry matter (DM)/ha of ryegrass from each megalitre of water whilst the industry average is only 1500 kg DM/ha per megalitre.

It is also vital that the application rate doesn’t exceed the water infiltration rate of the soil, which is how fast the soil can absorb water. If the infiltration rate is exceeded, the resulting run-off wastes water, causes erosion and nutrient loss and decreases application uniformity. As a guide, best application rates for most soils range between 10 mm to 20 mm/hr.

**Know the application rate and amount that wets the effective root zone without causing run-off.**
Guide to sprinkler application rates (mm/hr)

This guide is for healthy soils and indicates maximum rates above which runoff would occur.

**Note:** Applications on soils with degradation problems, such as surface sealing or compacted soil layers within the soil profile, would need to be lower to avoid runoff.

Check for soil structural decline. Is something needed on soil structure? See Module 1 for more information.

**Distribution uniformity**

Distribution uniformity simply means the evenness of water application over the ground.

To measure distribution uniformity cans are used to catch water from the irrigation unit operating in a fixed position or passing over them.

Since the RWUE project commenced the Dairy and Fodder industries have had over 450 system checks performed on irrigation plants to ascertain irrigation efficiencies across the range of systems in place. The Team has documented that there have been systems performing at each end of the spectrum and all the way between. The figure below depicts the application uniformity results of 133 irrigation systems that have been tested throughout the state. The units are expressed as Co-efficient of Uniformity (CU), which is a similar measurement to DU%, the formula is expressed in Module 5.

**System audit figures for CU% from DFWP evaluations**

The RWUE project has found that making slight changes to the irrigation system can lead to much improved distribution uniformity. For example, the replacement of single jet sprinklers with double jet sprinklers on a side roll operating at 44 psi (302 kPa) increased the DU by 25%.

A new rotator sprinkler package and the removal of the end guns on a travelling boom showed an increase in DU of 14%.

Under-watering areas within the paddock can lead to:

- Uneven growth
- Plant stress
- Reduced crop yields
Excessive watering may result in:

- Reduce yield by leaching of nutrients
- Increase disease incidence
- Fail to stimulate the growth of valuable plant material
- Water logging

Excess water can be related to other resource & economic losses such as:

- Energy for pumping
- Fertilizer leaching
- Chemical loss from leaching and/or run-off
- Investment loss due to poorly designed irrigation systems
- Ultimate yield losses

The following example highlights the cost comparison between systems performing at 70%DU and 90%DU. From the graph above it can be determined that an extra 11mm and 3mm of irrigation water would need to be applied to deliver 25mm to the driest area on the paddock for the respective operating DU% in this example. The table below outlines expected costs of such performance.

<table>
<thead>
<tr>
<th></th>
<th>70% DU</th>
<th>90% DU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump cost @ 10c/kWh</td>
<td>$44/ML (median for 51 evaluations)</td>
<td>$44/ML</td>
</tr>
<tr>
<td>Extra water applied</td>
<td>11mm – 110,000 L/ha</td>
<td>3mm – 30,000 L/ha</td>
</tr>
<tr>
<td>Pumping Loss</td>
<td>$4.84/ha</td>
<td>$1.32/ha</td>
</tr>
<tr>
<td>Water Loss @ $20/ML</td>
<td>$2.20/ha</td>
<td>$0.60/ha</td>
</tr>
<tr>
<td>TOTAL/ha</td>
<td>$7.04</td>
<td>$1.92</td>
</tr>
</tbody>
</table>

Clearly as tens or hundreds of hectares are irrigated there is significant water and cost savings to be realised from systems with higher DU%. The above example does not account for improved yields or nutrient retention from higher performing systems or the potential of reduced pumping costs.

The table depicting application efficiency of various systems tested by the DFWP team demonstrates that there is a wide range of performance within an irrigation type, let alone between high and low pressure systems.
Poor DU% is inefficient and costly on a number of fronts:

- Increased water use and pumping costs to compensate for poor irrigator performance
- Applying too much water in some areas to ensure the minimum amount of water reaches under watered areas
- Areas of crop stress where insufficient water is applied

Improving distribution results in:

- Application of less water
- Crop growth is more even
- Decrease in pumping time
- Yield increase

Factors that can affect sprinkler performance:

- Worn nozzles
- Sprinkler pressures
- Pressure regulators on centre pivots and linear moves
- Wind conditions
- Travelling gun rotation

Field trials have shown that several factors can be implemented to achieve improved DU% such as:

- Properly designed irrigation systems
- Understanding the system that you are using (pressure tolerances of sprinklers, application limitations)
- Maintaining the system for peak performance (sprinkler and nozzle wear, drive mechanisms, pump delivery etc.)
- Overall management (system checking of equipment to monitor application rates and pumping costs)
- Insist on a system check by the supplier to include distribution uniformity as part of the purchasing contract

**Pump efficiency**

This is the amount of usable work done by the pump as a percentage (%) of power delivered to the pump shaft and is determined by the pump manufacturer under factory testing.

**How to calculate the efficiency of your pump**

- Record the pumping rate from your flow meter – in litres per second.
- Record kilowatts of electrical energy from your electricity meter (see overleaf)
- Record the operational pressure reading from the pump pressure gauge
- Measure the suction lift in metres (vertical distance between the pumping water level and the pump)
- Calculate pump efficiency
Irrigation systems

Notes

Pe = 0.98 x Q x H
KW x Me x Df

Pe = pump efficiency as a %
Q = pump discharge in litres/second
H = total pump head in metres
kW = electrical kilowatts
Me = motor efficiency as a decimal

7.5 – 18.5 kW use 0.88
22 – 55kW use 0.90
75kW and over use 0.92

Df = Drive factor

Direct coupled use 1.0
Gear drive use 0.95
Vee belt use 0.93
Flat belt use 0.88

<table>
<thead>
<tr>
<th>Calculations</th>
<th>Example</th>
<th>Your pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pump rate: litres per sec</td>
<td>Q 30</td>
<td></td>
</tr>
<tr>
<td>2. Electrical energy ()</td>
<td>kW 55</td>
<td></td>
</tr>
<tr>
<td>3. Pressure gauge: kPa x 0.102 or psi x 6.895 x 0.102</td>
<td>m 104.55</td>
<td></td>
</tr>
<tr>
<td>4. Suction lift</td>
<td>m 4</td>
<td></td>
</tr>
<tr>
<td>Total head</td>
<td>H 108.55</td>
<td></td>
</tr>
<tr>
<td>5. Motor efficiency</td>
<td>Me 0.92</td>
<td></td>
</tr>
<tr>
<td>6. Drive type</td>
<td>Df 0.93</td>
<td></td>
</tr>
<tr>
<td>7. Pump efficiency</td>
<td>Pe 0.98 x Q x H</td>
<td>0.98 x 30 x 108.55</td>
</tr>
<tr>
<td></td>
<td>KW x Me x Df</td>
<td>55 x 0.92 x 0.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 66%</td>
</tr>
</tbody>
</table>

Note: Compare pump efficiency to the pump performance curve to determine efficiency loss from wear and tear. Accurate measurements are required for assessment of pump efficiency and performance.

**Estimating the kw load of an installation**

The kilowatt load or demand of an installation at any time may be estimated accurately by observing the period of time required for the kWhr meter disc to rotate a specified number of revolutions. This information, in conjunction with the meter constant (that is, the number shown on the kWhr meter name-plate as “Revs of meter disc per kWhr”), may be used as a basis for a simple calculation as follows:

\[
\text{kW} = \frac{R \times 3.600}{t \times c}
\]

Where kW = Demand in kilowatts at time of reading
R = Number of disc revolutions timed with stop watch (this may be any convenient number)
t = Time in seconds for “R” revs
c = Meter constant in revs per kWhr
Example

Suppose it is found that 10 revolutions of a meter disc take 20 seconds and the “Revs per kWhr marked on the meter is “50” then:

\[
\begin{align*}
\text{kW} &= \frac{10 \times 3,600}{20 \times 50} \\
&= 36 \text{ kilowatts}
\end{align*}
\]

Most pump installations will have three separate electricity meters, that is, one for each phase. In this case, all three meters must be read separately and each one calculated as shown above. The three totals are then added together. This will give the total kilowatts of power being drawn by the motor during operation.

**Alternative method**

This method requires recording the total kilowatt consumption shown on the electricity meters during normal operation. These totals are again recorded some hours later. The original readings are subtracted from the final readings to give total kW of power used. This total is divided by the number of hours of running time recorded, to give the total hourly consumption in kilowatts. This method works well where a single poly phase meter is used or when a new digital meter is installed. Digital metres regularly scroll through a number of readings, including a progressive total of all kilowatts consumed.

**Pump issues**

A vital component of all irrigation systems is the pump. There are a variety of pumps available including centrifugal, turbine and others.

The typical cost of pump ownership is made up of capital cost 5%, maintenance 8%, and power bills 87%. Pump efficiency is a measure of the amount of work done by the pump compared to the power delivered to the pump shaft. The target for pump efficiency is 70%. However, some pumps are simply not capable of reaching this level of efficiency.

**Causes of poor efficiency**

**Poor pump selection** – pumps will generally operate at their maximum efficiency level when performing the task for which they were designed. Therefore pump selection should be made while considering the required duties of the pump. It is important to check pump performance curves to help correctly match the pump to its duty requirements.

**Worn or damaged pumps** – factors that can damage pumps and therefore impact on pump performance include:

- Pumping impurities (sand),
- Poor water quality,
- Cavitation,
- Poor maintenance,
- Poor suction conditions,
- Blocked/clogged impellers,
- Everyday wear and tear.

**Impacts of poor efficiency**

If the pump is not delivering the required pressure and flow rate of the irrigation system, irrigation performance will be poor. This will result in poor distribution uniformity (DU) producing dry areas in the paddocks. This will lead to lost production or extra water used to compensate the dryer area.
What is needed to check pump efficiency

The three measurements needed to calculate pump efficiency are:

- Power use (kilowatts or litres of diesel),
- Water flow rate (L/sec), and
- Pump operating pressure.

When these three factors are measured accurately, a formula is used to determine the efficiency of the pumping unit.

It is recommended that more than one pump efficiency test should be conducted, under various operating conditions, to more accurately determine overall pump efficiency.

Pump rules of thumb

- 1m head of water = 1.5 psi (1.42),
- 1 Mega-Litre of water evenly applied to;
- 4 hectares = 25mm,
- 10 acres = 1 inch,
- Divide GPH by 800 to get L/sec,
- 1 psi = 6.88 KPA,
- 1.08 nozzle at 60 psi applies 1ML in 22 hours,
- Pump operating costs = 35c x psi at pump,
  – pumps must be carefully selected to achieve maximum efficiency
- A Distribution Uniformity (DU) of 80% or better will improve water use efficiency
- Example operating pressures and pumping costs for irrigation systems:

<table>
<thead>
<tr>
<th>Irrigation System</th>
<th>Range of Operating Pressures</th>
<th>Typical Operating Costs per Mega-Litre*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip and trickle systems</td>
<td>7 – 15 psi</td>
<td>$15.75 (45psi at pump)</td>
</tr>
<tr>
<td>Centre pivot and laterals</td>
<td>6 – 20 psi</td>
<td>$17.50 (50 psi at pump)</td>
</tr>
<tr>
<td>Solid set sprinklers</td>
<td>40 – 50 psi</td>
<td>$28 (80 psi at pump)</td>
</tr>
<tr>
<td>Travelling gun irrigators</td>
<td>70 – 90 psi</td>
<td>$42 (120 psi at pump)</td>
</tr>
</tbody>
</table>

* Based on 10c/kWhr and pump efficiency of 70%
Important to know

The main reasons for poor pump performance and high pumping costs are:

- Pump wear caused by solids, such as sand particles in the water
- Pump wear from cavitation, caused by poor pump site selection and suction lift being too high
- Undue wear of motor and transmission components
- A poor match between pump capacity and the pump duty required by the system
- System pressure requirements too high, due to undersized pipes in the distribution system and/or high elevation pressure losses

Irrigated pasture savings and costs

A great deal of effort and expense goes into storing and applying water to grow feed.

Although this also involves better grazing management, there is plenty of potential to get more production from a water supply. The aim is to make every dollar spent on irrigation go towards growing feed. Efficient operators water to the requirements of their pastures and crops.

Applying too little water reduces production. Applying too much wastes water, increases pumping costs and causes waterlogging. Excessive runoff and deep drainage increases loss of nutrients from the paddock and the risk of polluting groundwater and streams.

Most operators aren’t sure if their irrigation hardware is performing efficiently. This is an area where cost and labour savings, along with improvements in crop and pasture growth can be made.

Gain irrigation hardware operating and cost efficiencies by:

- Ensuring nozzle pressure is within optimal operating range
• Checking irrigation system design and layout to keep pumping costs to a minimum
• Matching pump size to duty,
• Maintaining hardware to minimise energy use and water losses from leakage

Guide to effective root depth (cm)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Ryegrass</th>
<th>Lucerne</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy clay</td>
<td>10 - 20</td>
<td>50 - 60</td>
<td>50 - 60</td>
</tr>
<tr>
<td>Loam</td>
<td>20 - 30</td>
<td>60 - 80</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>25 - 35</td>
<td>70 - 90</td>
<td>80</td>
</tr>
</tbody>
</table>

Important to know
Some soil profiles may restrict root growth either due to compacted soil layers or an abrupt change in soil type down the profile.

Checking irrigation hardware

Purpose
Check pumps, irrigators and pipes to:
• Reduce energy use and other operating costs
• Improve irrigation system performance for better water application and feed production
• Ensure hardware is running at full potential

Knowing whether your irrigation system is efficient basically involves checking:
• What the hardware does deliver, or its current capacity
• What the hardware should deliver, or its specified capacity

Specified capacity is what the irrigation system is designed to achieve if operating well due to good installation and minimal wear. When current capacity doesn’t match specified capacity, the system is operating inefficiently and may require some maintenance or upgrading.

Irrigator and pump measurements are required when checking current irrigation system capacity or performance. Delivery pipes may also need to be checked. Checking is important as the potential benefits from improved production and saved labour, energy or fuel, water and possible leached nutrients are worth the inconvenience.

Checking irrigation practice

Purpose
Check irrigation application and scheduling to:
• Improve production and reduce irrigation costs
• Minimise water and nutrient losses
Important to know

Checks of irrigation systems on Queensland dairy farms in 2001 indicated that about 40% of systems had distribution uniformity (DU) below 70%.

When upgrading an irrigation system specify a DU requirement above 80%.

Get the DU close to, or above, the target benchmark before adjusting irrigation times, application amounts and schedules, and before using any soil moisture monitoring tools.

Scheduling practices

Scheduling is basically about how much water to apply and when to apply it so that moisture in the root zone remains sufficient for the pasture or crop to grow at or near its maximum rate. ‘How much’ is what’s needed to re-wet the effective root zone. ‘When’ is influenced by weather conditions but, in general terms, should always occur before the root zone dries out too much.

Schedule irrigations to match and maintain the pasture or crop’s water requirement for active growth. Water application of 1 mm for each 1 cm of the pasture or crop’s effective rooting depth should recharge soil moisture from the refill to full point on fertile, well-structured clay and loam soils.

This rule is conditional on water being applied. The trick is to know when the soil moisture needs to be refilled to maintain good plant growth. There are several ways of determining this with varying degrees of accuracy, effort and expense.

Most farmers presently schedule irrigations based on general recommendations or on recommendations adjusted for local conditions by trial and error. Scheduling can be further improved, however, by using evaporation and soil moisture measurements. Use weather indicators or measurements of soil moisture in the effective root zone to help best determine when to irrigate.

Trial and error

Most farmers use this approach. General recommendations for scheduling irrigation provide a guide that is modified by local experience of soil conditions and seasonal weather. The look of the crop, for example, leaf wilting, and the prevailing weather conditions help to tune irrigations in the short-term.

Accuracy depends very much on skills acquired from experience. Most who use this method tend to over-water just to be on the ‘safe-side’. Up to 30% water savings are possible when experience is combined with evaporation and/or direct soil measurements.
Module 3 – Pumps

Worn parts help you part with your money

When you can find the time, it is wise to check the wear on all your farm machinery, including pumps.

![Worn impellers may reduce pressure, causing uneven water distribution](image)

Impeller wear

If the impeller is worn this can significantly increase your irrigation costs. Abrasive sand can wear the impeller, as can positioning the pump too high above the water source.

**Why is this so?**

- When the pump is positioned too high, gas is drawn out of the water within the suction pipe, due to reduced pressure
- When the gas is subject to the high pressure within the pump it implodes and erodes small amounts of metal from the impeller

A worn impeller can mean a poor distribution of water because it cannot transfer the power from the engine and so produces less pressure. It acts like an impeller that is too small. Once pressure falls, the water at the 'business end' of the irrigation system, the sprinkler heads, is not distributed in a uniform pattern. Often the farmer cannot detect this poor distribution by eye, although it can be measured.

'Poor distribution of water means less than optimal growth and yield across your whole crop, which ultimately affects profitability,' Alan Richards, Irrigation Officer, Paterson.

Testing the pump performance

To test how well your electric pump is working you can time the electricity meters and relate power consumption to water flow. A good result for your pump is between 200 and 300 kilowatt hours per megalitre pumped.

You can also calculate actual pump efficiency if you fit a pressure gauge to the pump delivery.

**Does a worn pump always cost more?**

Yes. Although pumping at a reduced pressure can save on hourly pump costs, it causes poor distribution. This reduces crop yield and quality, which will cost far more.

Cost check

Pump costs vary greatly between systems. Consider the following example. Pump running costs around $25/ML for normal medium pressure sprinklers and $35/ML for high pressure (90 psi) sprinklers. But suppose the pump is damaged or worn: it could, for example, cost an extra $10 per megalitre (ML) on top of these costs.
This means, if a replacement pump costs around $2000, pumping just 200 ML equates to the cost of a new pump. (Two hundred megalitres is enough to irrigate about 35 hectares at 6 ML/ha for the season.)

In other words, if irrigating forty hectares for more than one season with an inefficient pump, the extra energy it requires would cost significant dollars.

**Impeller troubleshooting**

How else can an impeller cause pumping problems?

- No water or a reduced flow: stones may be blocking the impeller. (This can happen if the suction strainer is inadequate or rusted out; or if there is not enough surface area for the strainer to operate)
- Reduced discharge pressure: impeller may be partially clogged or damaged, or it may be the wrong diameter

**Savings in pumping costs – electric**

(If pump efficiency improved 60% to 75%)

<table>
<thead>
<tr>
<th>Pumping head</th>
<th>Savings KWh/ML</th>
<th>Dollar savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume pumped in megalitres</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>1700</td>
</tr>
<tr>
<td>40</td>
<td>43</td>
<td>6500</td>
</tr>
<tr>
<td>50</td>
<td>54</td>
<td>5400</td>
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<td>55</td>
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<td>85</td>
<td>92</td>
<td>920</td>
</tr>
<tr>
<td>90</td>
<td>97</td>
<td>1000</td>
</tr>
<tr>
<td>120</td>
<td>129</td>
<td>1300</td>
</tr>
</tbody>
</table>

Many other pump faults can cause these problems:

- Blockages in the suction pipe or opening
- Air pocket or air leak in the suction line
- Speed too low
- Discharge head or suction lift too high
- Wrong direction of rotation
- Priming-casing and suction pipe not completely filled with water
- Mechanical defects
- Air leaking into the pump casing

**Savings in pumping costs – diesel**

(If pump efficiency improved 60% to 75%)

<table>
<thead>
<tr>
<th>Pumping head</th>
<th>Savings Litres/ML</th>
<th>Dollar savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume pumped in megalitres</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>2250</td>
</tr>
<tr>
<td>40</td>
<td>12</td>
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<td>90</td>
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<tr>
<td>120</td>
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<td>1850</td>
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</table>
## Performance Table

<table>
<thead>
<tr>
<th>Sprinkler</th>
<th>Diameter</th>
<th>Nozzle Diameter</th>
<th>Sprinkler Pressure</th>
<th>Output</th>
<th>Wetted Width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>ins</td>
<td>kPa</td>
<td>PSI</td>
<td>GPM</td>
</tr>
<tr>
<td>Pumps</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>19.0</td>
<td>0.71</td>
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<td>200</td>
<td>21.34</td>
<td>280</td>
<td>21.34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprinkler</th>
<th>Pressure</th>
<th>Output</th>
<th>Wetted Width</th>
<th>Approx Lane Spacing</th>
<th>Full Circle Precipitation Rate (avg)</th>
<th>Approximate Area per Run</th>
<th>5.5 Hour Run</th>
<th>11 Hour Run</th>
<th>22 Hour Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinkler</td>
<td>kPa</td>
<td>PSI</td>
<td>GPM</td>
<td>m ft</td>
<td>mph</td>
<td>ha</td>
<td>mm</td>
<td>ins</td>
<td>mm</td>
</tr>
<tr>
<td>Sprinkler</td>
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</table>

Note: approximate lane spacings calculated using 0.65 wind factor (65% of the wetted width/sprinkler diameter)
**Estimating the Kw load of an installation**

The kilowatt load or demand of an installation at any time may be estimated fairly accurately by observing the period of time required for the kWh meter disc to rotate a specified number of revolutions. This information, in conjunction with the meter constant (i.e. the number shown on the kWh meter nameplate as "Revs of meter disc per kWh"), may be used as a basis for a simple calculation as follows:

\[
\text{kW} = \frac{R \times 3,600}{t \times c}
\]

Where kW = Demand in kilowatts at time of reading:
R = Number of disc revolutions observed
(t may be any convenient number)
t = Time in seconds for "R" revs
c = Meter constant in revs per kWh

Examples:
Suppose it is found that 10 revolutions of a meter disc take 20 seconds and the "Revs per kwh" marked on the meter is "50" then:

\[
\text{kW} = \frac{10 \times 3,600}{20 \times 50} = 36 \text{ Kilowatts}
\]

Most pump installations will have three separate electricity meters, i.e. one for each phase. In this case, all three meters must be read separately and each one calculated as shown above. The three kilowatt totals are then added together. This will give the total kilowatts of power being drawn by the motor during operation.

**Pump efficiency**

This is the amount of usable work done by the pump as a percentage (%) of power delivered to the pump shaft and is determined by the pump manufacturer under factory testing.

Pumps with a reduced efficiency of 20% have a 25% increase in power usage.

How To Calculate The Efficiency Of Your Pump
1. Record the pumping rate from your flow meter: - litres per second
2. Record kilowatts of electrical energy from your electricity meter as described by the leaflet on Electrical Energy Costs
3. Record the operational pressure reading from the pump pressure gauge
4. Measure the suction lift in metres (vertical distance between the pumping water level and the pump)
5. Calculate pump efficiency

\[
Pe = \frac{98 \times Q \times H}{kW \times Me \times Df}
\]

Pe = pump efficiency as a %
Q = pump discharge in litres/sec
H = total pump head in metres
kW = electrical kilowatts
Me = motor efficiency as a decimal (from manufacturer's sheets)
\[
\Rightarrow 22-55 \text{ kW output: use } 0.90
\]
\[
\Rightarrow 75 \text{ kW and over: use } 0.92
\]
Df = drive factor = 100 - estimated drive loss %
(Drive Loss examples: V-belt 7%, flat belt 12%, gear 5%)

**Note:** Compare Pe on your pump curve to determine efficiency loss from wear and tear.

Accurate measurement of pumping rate Q is required for specific assessment of pump efficiency and performance.

<table>
<thead>
<tr>
<th>Calculations</th>
<th>Example</th>
<th>Your Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump rate: litres per second Q</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Electrical Energy from Page No. 5 kW</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Pressure gauge: 1025 kPa x 0.102 m</td>
<td>104.55</td>
<td></td>
</tr>
<tr>
<td>Suction lift m</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total Head H</td>
<td>108.55</td>
<td></td>
</tr>
<tr>
<td>Motor efficiency 60 kW motor Me</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>Transmission: vee belt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump efficiency Pe = 0.98 x Q x H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KW x Me x Df</td>
<td>96 x 30 x 108.55</td>
<td>55 x 0.92 x 0.93</td>
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<tr>
<td></td>
<td>66%</td>
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Electrically driven pump efficiency & cost calculator No. 1
(use when total power consumption is recorded)

**Inputs**

**Irrigation**
- Date (enter as dd-mm)
- Time (enter as hh:mm)

**Pump and Motor**
- Flow meter
- Operating pressure kPa
- Suction lift m
- Rated motor output kW
- Drive type Direct or Other

**Electricity meters**
- No 1 – high rate dial kW
- No 1 – low rate dial kW
- No 2 – high rate dial kW
- No 2 – low rate dial kW
- No 3 – high rate dial kW
- No 3 – low rate dial kW
- Multiplier (usually not applicable)

**Electricity Tariff**
- Tariff – off-peak rate c/kWh
- Tariff – peak rate c/kWh
Electrically driven pump efficiency & cost calculator No. 2
(Use when electricity meter disc rotations are timed)

**Inputs**

<table>
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<tr>
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</tr>
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<tbody>
<tr>
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<td></td>
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<tr>
<td>Time</td>
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<table>
<thead>
<tr>
<th>Pump and Motor</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction lift</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated motor output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive type</td>
<td></td>
<td></td>
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</tbody>
</table>

| Electricity meters | | |
| Revs/kWh as marked on meter |     |
| Multiplier as marked on meter | |
| Number of disc revolutions timed with stop watch | |
| Time taken for disc revolutions timed | seconds |

| Electricity Tariff | | |
| Tariff – low rate  | c/kWh |
| Tariff – high rate | c/kWh |

\(^1\) Three (3) phase units may have a single polyphase meter or three (3) metres (one for each phase). In the latter case each meter is to be read and the individual kWs totalled.

\(^2\) Choose a reasonable number of disc revolutions to time.

Diesel Motor Driven Pump Efficiency & Cost
(Use for diesel powered pumps)

<table>
<thead>
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<td>Time</td>
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</tbody>
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<table>
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<th>Start</th>
<th>End</th>
</tr>
</thead>
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<tr>
<td>Operating pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction lift</td>
<td></td>
<td></td>
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<tr>
<td>Rated motor output</td>
<td></td>
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<td>Drive type</td>
<td></td>
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</tr>
<tr>
<td>Price</td>
<td>c/L</td>
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<tr>
<td>Rebate</td>
<td>c/L</td>
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## Metric converter

**Graham Harris, RWUEI Cotton & Grains, DPI/Cotton CRC, Toowoomba**

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Input</th>
<th>Units</th>
<th>Symbols</th>
<th>Output</th>
<th>Units</th>
<th>Symbols</th>
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<td>$/yd²</td>
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<td>$/m</td>
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<td>$/m</td>
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<td>kPa</td>
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<td>l/ha</td>
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<td>Ml</td>
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<td>Ml/ha</td>
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<td>mm/ha</td>
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<td>ac ft</td>
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<td>megalitres</td>
<td>Ml</td>
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<td>ac ft/ac</td>
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<td>megalitres/hectare</td>
<td>Ml/ha</td>
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### Volume

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</thead>
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<td>Litre (L)</td>
<td>Cubic metre (m³)</td>
</tr>
<tr>
<td>Litre (L)</td>
<td>1</td>
</tr>
<tr>
<td>Cubic metre (m³)</td>
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<tr>
<td>Imperial gallon (Imp gal)</td>
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### Flow rate

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<td>Litre per minute</td>
</tr>
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<td>Litres per second</td>
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</tr>
<tr>
<td>Litres per minute</td>
<td>0.016</td>
</tr>
<tr>
<td>Cubic metres per hour</td>
<td>0.278</td>
</tr>
<tr>
<td>Imperial gallons per min</td>
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### Length

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<th>mm</th>
<th>cm</th>
<th>m</th>
<th>km</th>
<th>in</th>
<th>ft</th>
<th>mile</th>
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<td>0.001</td>
<td>-</td>
<td>0.039</td>
<td>0.003</td>
<td>-</td>
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<tr>
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<td>10</td>
<td>1</td>
<td>0.01</td>
<td>-</td>
<td>0.39</td>
<td>0.033</td>
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<tr>
<td>Metre</td>
<td>1000</td>
<td>100</td>
<td>1</td>
<td>0.001</td>
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<td>3.281</td>
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Pumps 33
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<th>km</th>
<th>-</th>
<th>1000</th>
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<th>-</th>
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<td>1</td>
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<td>-</td>
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<td>ft</td>
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<td>30.48</td>
<td>0.305</td>
<td>-</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Mile</td>
<td>mile</td>
<td>-</td>
<td>-</td>
<td>1610</td>
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**Pressure**

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<th>psi</th>
<th>m</th>
<th>ft</th>
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<tbody>
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Module 4 - Irrigation scheduling

Scheduling practices

In order to optimize crop growth the plant water demands must be met, irrigation is pivotal in the role to achieve this requirement. One objective of irrigation management is to supply a desired amount of water to the crop at a specific time, this we term “irrigation scheduling.” When the project commenced in 1999 it was discovered that whilst many farmers had the intentions to schedule water they simply could not as their irrigation systems were not capable. With the Financial Assistance Program many producers have installed new irrigation plants, e.g. Centre Pivots, which may be programmed to deliver specific amounts of water on time.

When scheduling irrigation a few key factors need to be considered:

- rate of forage water use
- water availability within the forage root zone
- when to apply irrigation
- how much water to apply
- rainfall pattern, rate of evaporation
- characteristics of the irrigation system, e.g. DU%, nozzle type etc.

Irrigation scheduling can be described simply as the frequency of irrigation events and the volume of water applied at each application. The difficulty lies in minimising water stress by determining the correct irrigation interval and the right amount of water to consistently achieve target forage production, at the required quality, whilst minimising over watering.

What we tend to see in practice is too much water applied in the cool season, and not enough applied during spring.

Scheduling is basically about how much water to apply and when to apply it so that moisture in the root zone remains sufficient for the pasture or crop to grow at or near its maximum rate. ‘How much’ is what’s needed to re-wet the effective root zone. ‘When’ is influenced by weather conditions but, in general terms, should always occur before the root zone dries out too much.

Important to know

Production from shallow-rooted plants, like ryegrass, will drop significantly before they show any signs of water stress. In fact, even deep rooted crops suffer production losses well before they display visual signs.

If your irrigation schedule is wrong, you may lose production and not know it!

Get irrigation scheduling right and you are a long way towards maximising crop production and reducing costs!

The diagram below shows the successive wetting and drying that occurs in the root zone following irrigations. The operator got the last irrigation spot-on and this is what to aim for!
Useful to know

Technical terms for the soil moisture that plants are able to use include:

- **Readily Available Water (RAW),** or the water held in the soil between the full and refill points that supports good plant growth (see blue shading above).
- **Available Water Capacity (AWC),** or the total plant available water the soil can store including that used below the refill point when plants are stressed.

Water application of 1 mm for each 1 cm of the pasture or crop’s effective rooting depth should recharge soil moisture from the refill to full point on fertile, well-structured clay and loam soils.

This rule is conditional on water being applied at the refill point before plants are water stressed.

There are a number of ways to determine irrigation scheduling:

1. Intuition and experience – rely on past experience.
2. Plant assessment – look for signs of wilting, stem sap flow
3. Soil assessment – corer, soil water monitoring device
   - Gravimetric (g/g)
   - Volumetric (cm³/cm³) - EnviroSCAN
   - Water potential (kPa) – Gypsum block, tensiometer
4. Climate – class A pan (mm), FAO56 evapotranspiration (mm)

The trick is to know when the soil moisture needs to be refilled to maintain good plant growth. The four methods mentioned above vary in expense and accuracy.

Most farmers presently schedule irrigations based on general recommendations or on recommendations adjusted for local conditions by trial and error. Scheduling can be further improved, however, by using evaporation and soil moisture measurements.

Use weather indicators or measurements of soil moisture in the effective root zone to help best determine when to irrigate.
Scheduling Assistance - iCalc

To assist with scheduling irrigation the DFWP team developed an irrigation calculator, iCalc. This program is designed to help with the determination of crop water demands. iCalc incorporates climate data, research data on crop yields, water use data and FAO56 information to provide a predicted ML/ha/yr for a range of crops and pastures.

General scheduling recommendations: examples

There are general recommendations for irrigation schedules and examples are provided for ryegrass and ryegrass/clover. These recommendations should be adjusted to allow for on farm conditions.

Ryegrass

**After planting**

Ideally the seedbed should be moist from either rain or pre-plant irrigation. Light irrigations (15 mm) should follow as soon as possible after sowing and be continued every 4-5 days during the first 3 weeks to keep the surface moist. The frequency can then be reduced to every 2 weeks with applications of no more than 25 mm each time. Less frequent but higher rates of application, such as greater than 50 mm every 20 days, will result in soil moisture going beyond the root zone and this may cause problems on heavy clay soils.

**Spring**

In spring, irrigation should be applied at 10-day intervals (25 to 45 mm) as warmer weather increases the chance of water stress. It is critical that the soil in the effective root zone mostly remains moist. Failure to maintain this can result in lower production and a shorter growing season. It is important to recommence irrigation early enough for the last paddock in the cycle to be watered well before wilting occurs.

Ryegrass/Clover

Clover should be irrigated in the same way as ryegrass until November. It is essential to monitor the clover to ensure it is not stressed during the summer months.

Trial and error

Most farmers use this approach. General recommendations for scheduling irrigation provide a guide that is modified by local experience of soil conditions and seasonal weather. The look of the crop, for example, leaf wilting, and the prevailing weather conditions help tune irrigations in the short-term.

Accuracy depends very much on skills acquired from experience. Most who use this method tend to over-water just to be on the ‘safe-side’. Up to 30% water savings are possible when experience is combined with evaporation and/or direct soil measurements.

Scheduling tools

**Evaporation measurements**

Evaporation measurements can provide an estimate of how much water pastures and crops are using. Standard adjustment values or crop factors are used to convert the evaporation from an open pan to a ‘paddock evaporation plus plant water use’ measurement. This, combined with standard soil type classifications, allows change in soil moisture to be calculated over various time intervals.
Some inaccuracies may occur with this method, due to the number of estimates involved, but scheduling using evaporation can be successful if on-farm conditions are also taken into account. Evaporation data is obtainable from the closest official meteorological station or, more accurately, from an on-farm evaporation pan. A farm rain gauge is required since rainfall needs to be entered into the scheduling calculations.

**Farm conditions and irrigation scheduling**

The irrigation system capacity is fundamental when scheduling irrigation, farm conditions that need to be checked and allowed for when irrigating are:

- Local weather - how weather conditions vary across the farm due to different landforms
- Soil variations - how soil type changes and affects soil moisture storage and availability
- Hydrology - how water moves through the farm landscape

**Local weather**

One farm can have several different microclimates, due to rain-shadow areas, and differences in evaporation rates that affect the rate of soil drying. Different schedules may therefore be needed on different parts of the farm.

It is important to know the direction of drying winds and the exposed slopes they affect. An example is westerly wind causing exposed slopes to dry out more quickly than protected areas. Exposed areas will need more water per application than protected areas. Updated four-day weather forecasts can aid in predicting when such winds will occur.

Storms can be localised with rain sometimes falling on only parts of the irrigated area. Generally, the irrigation schedule shouldn’t be varied until rainfall events exceed 10 mm, or you are sure of rain.

**Soil variations**

Water storage in the soil and its availability to plant roots both vary with soil depth and between soil types. This needs to be considered when scheduling.

Areas with a long history of cropping and/or have been subject to pugging may have a reduced capacity to capture, store and make water available to roots. Types of degradation include surface sealing, loss of friability and hard setting or compacted layers.

**Hydrology**

The way water moves over and through a farm can vary due to landform, geology, soil and climate of both the farm and catchment.

Some examples of hydrological features that signal a need for adjustments to irrigation scheduling and application are:

- Drier areas draining to wetter areas down-slope due to sub-surface flow of irrigation water. Application may need to be changed to a lesser amount, but applied more often
- Wet creek flats requiring less water per application
- Appearance of surface and underground springs
- Rising water tables and waterlogging, leading to a salinity hazard
- Salt affected areas

**Soil moisture measurements**

Combining the evaporation method with soil moisture measurements allows an operator to become highly skilled at irrigation scheduling.
**Soil moisture measurements & monitoring**

There are many soil moisture monitoring methods and devices available that vary considerably in cost and ease of use, including:

- Soil Auger (or dig stick) combined with ‘look and feel’
- Tensiometers
- Gypsum blocks
- Capacitance Probe

A guide to the accuracy, cost and ease of use of these follows:

<table>
<thead>
<tr>
<th>METHOD OR TOOL</th>
<th>ACCURACY</th>
<th>COST</th>
<th>LABOUR</th>
<th>MAINTENANCE</th>
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<tr>
<td>Soil Auger/ Dig Stick</td>
<td>Variable</td>
<td>Low</td>
<td>Initially high</td>
<td>Low</td>
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<td>Tensiometers</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
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<td>Medium/High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Neutron Probe</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Capacitance Probe</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

With most of these methods it is advisable to seek specialist advice and guidance on how to select monitoring sites and best use the different devices.

**Important to know**

The monitoring sites chosen for soil moisture measurements represent only a very small portion of the area being irrigated and therefore should be:

- Representative of the general soil type and pasture or crop growth characteristics of the irrigated area
- Located where water application is most uniform and well away from compacted wheel or cow tracks, disturbed soil and unhealthy plant patches

**Soil auger**

Soil moisture is monitored simply by ‘digging holes’ with a soil auger (100 mm diameter), gouge corer (dig stick) or shovel and the excavated soil then assessed for moisture content by ‘look and feel’.

**Tensiometers**

A tensiometer is a simple device comprised of a water-filled tube with a hollow and porous ceramic tip at one end and a vacuum gauge at the other. The ceramic tip is placed in the root zone and behaves like an artificial
plant root with the water tension in the tube and the gauge reading increasing as the soil dries out.

Tensiometers can only measure at one point in the root zone, so a few are needed to measure at different depths. Their use is restricted to coarser textured soils (sandy loams) since they cannot measure the entire range of soil water that is available to plants from fine textured soils (loams and clays).

**Gypsum blocks (Hanson Logger)**

Gypsum blocks provide another simple way of measuring soil moisture. Like tensiometers, readings from the blocks represent the suction plants need to exert through their roots to obtain water. The blocks need to be placed in the soil at different depths similar to tensiometers. Small electrical cables run from the block to the soil surface and are connected to a portable meter or logger when taking measurements. The Hanson Logger device has a simple display screen that enables producers to interpret soil moisture information in the paddock and is also able to be downloaded.

Gypsum blocks best measure the drier end of the soil moisture range and are therefore suitable for finer textured soils, however, research from the RWUE project has indicated they provide accurate results over a broad range of soil types.

Success with the blocks requires careful installation for correct positioning and ensuring close contact between the block and soil. Maintenance problems include block longevity, since they slowly degenerate when in contact with soil, and unreliable measurements after prolonged soil drying and shrinkage.

Cost – approx. $1,500

**Capacitance probe**

A capacitance probe, such as an EnviroSCAN, is a highly accurate but expensive device. It measures soil moisture using the dielectric constant of the soil profile and has a capacity to measure at different depths down the soil profile.

The sensing probe is placed in a tube in the ground and can record data automatically at specified time intervals to suit the soil and type of forage being grown. Capacitance probes can be fully automated for remote logging and transfer of data to a computer.
Enviroscan probe

Enviroscan logger
Module 5 - Low pressure systems

Introduction

Outcomes:

- Understand the different principals of low pressure irrigation.
- Understand the advantages of these systems compares to high-pressure systems.
- Manage an efficient low-pressure system.

Low pressure systems include centre pivots, lateral moves and sub-surface drip. Travelling booms may also be considered low pressure; solid set irrigation is generally referred to as medium pressure. Many low pressure systems have been installed through the Financial Assistance Scheme, they are generally considered to be more efficient across the board, particularly in the areas of power use, labour and irrigation distribution.

Application efficiency

Centre pivot application efficiency is a measure of the water loss associated with irrigation. Generally the major areas of water loss are:

- Sprinkler loss of fine water droplets
- Evaporative losses from either the soil surface or plant surfaces
- Run-off from irrigated field
- Deep percolation

Application efficiencies of greater than 90% are expected.

Evaporative and wind drift losses

Small droplets are subject to wind drift and evaporative losses. Droplet size is controlled by the emitter type, nozzle size and operating pressure.

Emitter location in relation to the crop height and the weather conditions influence spray losses. The losses due to wind drift and evaporation significantly increase as the emitter height increases. Different emitter types can limit wind drift losses by their direction/angle of spray. Evaporative and wind drift loss should not exceed 10%. There are numerous nozzles to cater for specific requirements, it is advisable that specific nozzles are fitted to perform the desired application.
**Run-off losses**

Potential run-off occurs when the application rate exceeds the soil infiltration rate. The application rate is controlled by the emitter discharge, wetted area and irrigation time. As the flow rate increases linearly along the centre pivot, the application rates at the outer spans may exceed the soil infiltration rate. Compaction and surface sealing due to large droplet size will decrease infiltration rates and increase potential run-off.

Spreading the water application over a larger area can reduce infiltration problems. This can be done by selecting an emitter with a larger wetted area or by using offset booms. Agronomic methods of minimising run-off can include increasing the surface water storage and soil infiltration rate by tillage practices, or retaining crop stubble. Runoff loss should be 0%, soil types, crop types and machine capabilities should all be considered to prevent runoff.

**Deep percolation losses**

Deep percolation occurs when water move through the soil pass the crop root zone. Irrigation scheduling and the use of smaller applied depths can control this. Deep percolation loss should be 0%.

**Recommendations**

Selecting the most suitable sprinkler package with consideration of the following can increase application efficiency for low pressure irrigation:

- Droplet size (wind drift and soil sealing)
- Sprinkler height (evaporation, wind drift and wetted area)
- Nozzle size (application rate)
- Emitter Type (wind drift and wetted area)

Growers can influence runoff and deep percolation. The climate controls the remaining losses, however the system can be designed to limit such losses.

**Distribution Uniformity**

Distribution uniformity refers to how even irrigation water is applied across the field. Fields that are irrigated with systems that have poor uniformity will have areas that receive the desired depth of water, but will have areas that are over and under irrigated. This variation in applied depth can lead to variation in yield.

**Non-uniformity factors**

Factors that contribute to non-uniform irrigation include:

- Incorrect emitter spacing, operating pressure and emitter configuration
- Nozzle size and position along machine
- Nozzle height, angle and wear
- Machine movement, step size and consistency
- Flow rate variation due to discontinuous end-gun operation, and variation in pump duty
- Runoff due to application rates exceeding soil infiltration rates

Variation in sprinkler pressure will affect uniformity for both regulated and non-regulated machines. Variation can occur with groundwater aquifer height change.
and should be managed so the machine is operating at the correct design pressure.

**Measuring uniformity**

The uniformity of water application for centre pivots can be measured by using catch cans and two transects across the travel path. There are standards for testing uniformity of centre pivots (ISO11595 and ASAE S436).

Before testing uniformity, the pivot should be operating at the pivot design pressure, and all nozzles must be checked and installed as per the nozzle chart.

**Coefficient of uniformity**

The coefficient of uniformity is used to describe the “evenness” of applications. For centre pivots the modified Heermann and Hein uniformity coefficient is used which weights the applied depths based on the circular area each catch can represents. The modified Heermann and Hein uniformity coefficient, $CU_{HH}$:

$$
CU_{HH} = 100 \left[ 1 - \frac{\sum S_s |D_s - \bar{D}|}{\sum D_s S_s} \right]
$$

where $D_s$ is the applied water depth for one collector position at a distance $S_s$ from the pivot point. The weighted applied depth, $\bar{D}$ is:

$$
\bar{D} = \frac{\sum_s D_s S_s}{\sum S_s}
$$

For centre pivot irrigation, $CU_{HH}$ results greater than 90% are considered the minimal level of acceptability.

Pressure regulators are used to maintain a desired sprinkler pressure and hence sprinkler output despite change in supply pressure.

**Pressure regulators**

Pressure regulators are required when:

- Elevation change is present between sprinklers
- Required flow rate varies due to end gun or corner operation
- Small sprinklers are supplied with excessive pressure, especially the first few spans on a centre pivot where required output is low, but pipe pressure is relatively high
A pump supplies more than one set of sprinklers that require a constant pressure, particularly with movable pivots and multiple pads.

Generally, pressure regulators are required when sprinkler output variation exceeds 10 percent. Pressure variation on non-regulated systems will experience poor water distribution uniformity.

**Undulating terrain**

The need for pressure regulator on undulating terrain depends on the degree of elevation difference, the sprinkler operating pressure.

For non-regulated systems, sprinkler output will vary depending elevation difference from pivot centre.

**Considerations**

- High value crops may warrant pressure regulators when only small areas are affected by poor uniformity
- Pressure regulators require 28 - 35 kPa greater supply pressure than the pressure rating to work. Regulators use energy to operate and increase pumping costs

The design pressure for a system should account for the greatest elevation difference, pipeline friction loss, pressure regulator rating and extra pressure to operate regulator.

**Fertigation and chemigation**

Fertigation and chemigation is the process of injecting fertiliser and chemical into irrigation water and applying through the irrigation system to the crop/field.
Fertigation

Advantages of fertigation:
- Nutrients can be applied on the basis of crop need
- The amount of water applied can control the placement of nutrients and readiness for plant uptake
- Uniform nutrient application if good system water distribution uniformity
- Eliminate some tillage operations
- Reduce application costs
- Less groundwater contamination, through reduced fertiliser use
- Minimise crop damage during application

Disadvantages of fertigation:
- Nutrient application uniformity is only as good as the system water distribution uniformity
- Some fertiliser materials often cannot be used
- Localised fertiliser placement is not possible
- Additional equipment is required for fertiliser injection

Chemigation

Advantages of chemigation:
- Uniform chemical application
- Chemical is applied where needed and in the correct concentrations
- Less expensive to apply chemical than conventional application methods
- Chemicals can be applied when other method are impossible, due to wetness, excessive wind, applicator availability
- Reduce application costs, soil compaction and crop damage associated with in-field spray equipment
- Less human contact

Disadvantages of chemigation:
- Requires high management of chemical with handling, calibration and scheduling
- Additional equipment is required for chemical injection
- Higher risk to water source

Water quality

Water quality should be considered before attempting to fertigate, as precipitation of some element in the fertiliser may occur. Other reactions may occur between the fertiliser and impurities in the water.

System design and construction

Due to the nature of fertigation/chemigation it may induce or accelerate corrosion of irrigation equipment and reduce the system life. Consideration should be given to the construction material and the fertiliser/chemical used.
Due to the small depth of water required for some fertigation / chemigation applications, high-speed gearboxes or a low flow sprinkler package may be required to apply depths of 2.5 – 5mm/pass. The irrigation system should be well flushed immediately after fertigation / chemigation.

Before any fertiliser/chemical injection, it is best to consult the chemical supplier. Make certain that there are no restrictions for injection and the product is labelled for the specific application.

**Wheel tracks**

*Factors influencing wheel track depth*

- Soil type (Heavier soils, higher water holding capacity and slower drainage)
- Number of revolutions
- Weight supported by each tower (Longer spans, more weight)
- Amount of wheel contact area with the soil surface

Wheel track depth should not exceed 100 mm

**Wheel track management**

There are a number of the management techniques that can be implemented to reduce the impact of wheel tracks. They include:

- Limit irrigations when the field is wet, avoiding unnecessary pivot revolutions
- Allow soil surface to dry between irrigation events (this however is not always feasible and may negatively impact crop production)
- Keep tyre inflation pressures at the manufacturer’s recommended level
- Consider working in circles
- Compaction of the wheel tracks, or the addition of polyacrylamides (track sacks)
- Fill the wheel track with crushed rock or other organic material
- Raise wheel tracks to prevent ponding

**Mechanical alterations**

A number of mechanical modifications can be done to reduce the depth of wheel tracks:

- Increase the tire-soil contact area by installing larger diameter/width tyres (the extra load on the drive mechanism should be considered)
• Install directional sprinklers either side of the tower to eliminate tower-water interception and keep the wheel track dry
• Install “boom backs” on the sprinklers near the tower
• Attach track-closing disks to each tower
• Alter sprinkler height to decrease tower-water interception;
• Use double length LEPA Hose
• Designing the system with shorter spans

Considerations must be given to the water application efficiency and uniformity when alterations are made to the system. Best management practices are required to manage wheel tracks.

The system capacity for centre pivot irrigation is a very important design and management issue. System capacity is the volume of water the irrigator is capable of supplying to a given area in a given time period (mm/day).

**System capacity**

*System capacity factors*

System capacity is dependent on the following:

- Peak crop water requirements
- Effective crop root depth
- Soil texture and infiltration rate
- Available soil water holding capacity
- Management Techniques
- Pumping capacity from water source

The flow rate required must adequately replenish water at a rate equal to the peak crop water use for a given area. Peak crop water use is dependent on the peak evapo-transpiration rate for the crop.

Not meeting the crop water use will result in plant stress and yield reduction.
System capacity calculation

The system flow rate is calculated knowing the required system capacity and the irrigated area. The total system flow rate, $Q$ (l/s), is:

$$Q = 0.1157 \times A \times d$$

where $A$ is total irrigated area (Ha), and $d$ is required system capacity depth (mm/day).

Moving towable pivots

Towable pivots systems are capable of irrigating a number of adjacent fields. Towable pivots lower the cost per irrigated hectare as the cost is spread over a number of fields. However, the system capacity of towable machines must be increased to account for the greater irrigated area and the non-irrigating time associated with moving the machine.

When moving towable pivots consideration should be given to the following:

- Lifting
- Towing speed
- Anchoring
- Towing in sloping fields
- Wheel tracks and ridges
- Towing accessories and pivot design

Lifting wheels

The rotation of the tower wheels is generally the longest operation in moving a pivot. There are a number of methods that can be used to lift the wheels on the towers before turning ready for moving:

- Hand jack (wallaby jack)
- Hydraulic jack
- Front-end loader
- Fitted hydraulic scissor jacks
Fitted scissor jacks cuts down the time to move a pivot but these are only available on hydraulic driven pivots

**Towing speed**
The towing speed should not exceed 5km/hour and ensure the spans do not bounce up and down. It is best to establish smooth tow lanes between adjacent fields.

**Anchoring**
When moving a pivot, the centre pivot should be placed in the same position every time. If they are in a different location each time, the pivot has to fight against existing wheel tracks.

The anchoring required for the pivot depends on the pivot length and soil type. Concrete pads are recommended for larger machines.

**Towing in sloping fields**
When towing on sloping fields it is possible for the pivot to free wheel. When moving over sloped country it is wise to use an additional tractor at the last tower as a brake if needed.

**Wheel tracks and ridges**
When a pivot is towed across rows, wheel tracks or ridges it is best to flatten and fill them before moving. Towing over rough ground can cause a greater amount of pull, especially if the wheels are sitting in wheel tracks. This can cause a significant amount of stress on the machine.

Generally the span lengths are the same so the wheel tracks are equal distance apart. When towing all towers move over the tracks at the same time, as span lengths match wheel rut spacing. Before moving the centre pivot to the tow lane for towing, the wheel ruts should be filled in.

**Towing accessories**
Some moveable pivots are fitted with reverse towing options. This allows the pivot to be towed backwards when a part circle field is irrigated due to physical obstructions.
**Gearboxes**

Gearboxes on towable pivots are different to non-movable pivots, as they are required to freewheel when in the tow position. The construction of the gearboxes means that extra stress is placed on secondary bearings when being towed.

**Pivot design**

The pivot tower design has a number of different options and is dependent on how often the pivot is moved:

- Two-wheel tower, ideal for frequent moves in any direction
- Three-wheel tower, ideal for towing in any direction
- Four-wheel tower, ideal when pivot points are in a straight line
- Skids, low cost and for infrequent towing

Some growers move the centre pivot as a lateral move with a tractor and a towed portable power supply without turning the wheels.

**Limitations of movable pivots**

Movable pivots are appropriate for supplementary irrigation when a number of fields are irrigated. During peak crop water use the pivot may require daily movement on light soils for shallow rooted crops. This constant moving means significant non-irrigation time, increased labour cost and lower system capacity.

Quite often the pivot is unable to meet the crop water requirement and signs of crop stress occur. Therefore movable pivots are usually only moved once or twice a year as part of a crop rotation program.

Some growers move the centre pivot as a lateral move with a tractor and a portable power supply without turning the wheels.
Factors influencing corrosion
Water quality is an important issue that influences the life of irrigation systems. Before installing an irrigation system, the quality of the water should be tested and a construction material be selected that will maximise system life.

A number of elements and properties can contribute to the corrosion potential for a system:

- pH level
- EC and total dissolved salts
- Sodium, chlorides and sulfates
- Water hardness and alkalinity
- Temperature and exposure time

Centre pivot material
Typically galvanised pipe is used when water quality is not a concern. A number of other products are available when water quality is an issue. The most appropriate material to use will depend on the specific water quality issue. The following are material options for centre pivots:

- Galvanised, not suitable for low pH and high chloride and sulfate concentration
- Aluminium, not suitable for high alkalinity
- Stainless steel, suitable for most conditions
- Under slung PVC, good for both acids and alkalis (pH range from 3 – 11)
- Epoxy coating and PVC or Polyethylene lined pipe, similar to under slung PVC
- Cathodic Anode corrodes a magnesium strip inserted into the bottom of the span rather than the zinc coating on the pipeline

Pivot management
The potential for corrosion can be minimised by good management techniques. They include:

- Ensuring drains are not blocked (Extended hoses can be fitted so water is not drained into the wheel tracks)
- Periodic flushing of solids with fitted flushing values
- Extensive flushing after chemigation and fertigation
- Ensure during pivot assembly that seals between main pipes are correct size and don’t allow water / solids to sit in the joins
- Limit the amount of time water is let sit static in the pipes

Economics of water quality
Water samples should be provided to manufacturers for analysis before designing centre pivot. If analysis indicates poor water quality, it is recommended that extra capital (approx. 13%) be outlaid to select a material that will minimise corrosion and increase the life span of the system.

The extended life of the machine will far out weigh the increase in capital cost. The pivot dealer should be able to recommend the best material based on the water quality and previous experience.
Solidset Irrigation

Solidset is classified as a medium pressure system that is set out in a grid pattern over a paddock. The DFWP team has tested many of these systems and have determined that the major influencing factor of distribution uniformity is the grid design. Once this system is installed it is very difficult to alter sprinkler or lateral spacing, adjustments can be made to operating pressure and sprinkler type if the desired DU% is not achieved.

The grid should be set up in a diamond pattern, with lateral spacing’s not exceeding 23m. Closer lateral spacing’s do increase set up costs, however these increased costs are more than off-set by operational savings achieved through lower pressure requirements thereby decreasing power and pumping costs in the system, DU% is also greatly improved. Sprinkler heights also influence performance and it is necessary to match a specific sprinkler to riser height to achieve optimum DU%, 1.8-2m is the general recommendation.
Module 6 - Economics

Irrigation System Comparison

The selection of the irrigation method that best meets the objectives for an irrigated area is the primary importance in the design process. A system may be well designed but inappropriate for the situation.

There are a number of factors affecting the selection of different systems. These need to be addressed with a whole farm plan that caters for development:

- Flexibility
- Lay of the land
- How much time do you have
- Maintenance (by whom)
- Levels of technology / breakdown
- Skill requirement for operation
- Labour requirement
- Life span of system
- Meet crop water demands and evapo-transpiration rates

During the project we have been able to compare various systems throughout Queensland, including:

- Drip Tape
- Side Rolls
- Hand Shift and Solidset
- Travelling Booms
- Travelling Guns
- Centre Pivots and Lateral Moves

There are desirable and undesirable facets of all systems and it has been found that the management of the differing systems is the key to optimising irrigation performance.

Technology is now commercially available to allow full automation of several types of irrigation systems. However this is not for all. Most importantly, the irrigation system must be suited to the owner – operators’ requirements and must be cost effective.

The table below compares an estimate of relevant on-going costs of various irrigation systems. Important factors are highlighted concerning initial set up costs and the flexibility of systems, e.g. drip, as well as other issues such as time and the costs of extra labour (maintenance) if the owner is unable to carry out daily tasks/repairs themselves. The maintenance costs of the low pressure systems: Pivots/Laterals, Drip and Solid Set may not be as high as indicated. The expected life may extend beyond that which is indicated.
Notes

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Capital $/ha</th>
<th>Labour @ $20/hr ($ per shift)</th>
<th>Maintenance $/ha/yr</th>
<th>Pump electricity $/ML</th>
<th>Expected life (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pivot</td>
<td>2500 - 3000</td>
<td>Negligible</td>
<td>50</td>
<td>28</td>
<td>20</td>
</tr>
<tr>
<td>Solid Set (automated)</td>
<td>2500 - 3500</td>
<td>Negligible</td>
<td>50</td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td>Traveller</td>
<td>2000 - 2500</td>
<td>20</td>
<td>200</td>
<td>76</td>
<td>10</td>
</tr>
<tr>
<td>Hand Shift</td>
<td>1500 - 2000</td>
<td>45</td>
<td>125</td>
<td>35</td>
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<tr>
<td>Drip</td>
<td>8000 - 9000</td>
<td>Negligible</td>
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</tbody>
</table>

Many variables come into play when working out the costs of a system and are dependent on existing infrastructure and the desired irrigation outcome. It is for certain, however, that low pressure systems are much cheaper to operate than high pressure systems and tend to have a higher life expectancy.

The pumping cost comparison between systems pumping 100ML/yr over 10 years is outlined in the table below. It should be noted that the DFWP team has determined from irrigation evaluations that the electricity savings have been considerably higher in many instances where systems were changed from high to low pressure, over 60% in some situations.

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Pump electricity $/ML</th>
<th>Total pump electricity $</th>
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</thead>
<tbody>
<tr>
<td>Pivot</td>
<td>28</td>
<td>28,000</td>
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<tr>
<td>Solid Set (automated)</td>
<td>42</td>
<td>42,000</td>
</tr>
<tr>
<td>Traveller</td>
<td>76</td>
<td>76,000</td>
</tr>
<tr>
<td>Hand Shift</td>
<td>35</td>
<td>35,000</td>
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<tr>
<td>Drip</td>
<td>20</td>
<td>20,000</td>
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</tbody>
</table>

**Comparison of irrigation systems**

**System advantages, disadvantages and notes**

**Soft hose travelling gun**

*Advantages*

- Suited to large, regular and relatively flat paddocks
- Variable run lengths possible
- Suitable for tall crops e.g. maize
- Labour requirements are high
- Acceptable distribution uniformity can be achieved if lane spacings are appropriate and wind conditions are favourable

*Disadvantages*

- High pressure requirements – higher pumping costs – high frictional head losses in hoses
- Greatly affected by wind
- Large droplets can cause compaction and damage to young plants
- Unreliable on sloping country (7%)
• Requires long straights to be labour efficient
• Usually requires a tractor as an anchor
• Hose replacement (4-12yrs)
• Regular maintenance

**Hard hose travelling gun**

**Advantages**
- Suited to large relatively flat paddocks
- Unaffected by terrain
- Runs up to 400 metres
- Light carriage system is an advantage over cultivated ground, minor crop loss

**Disadvantages**
- High pressure – higher pumping costs, high frictional head losses
- Distribution affected by wind
- Average life span of 10 yrs

**Ezi or bike shift**

**Advantages**
- Relatively inexpensive to install
- Adaptable to irregular slopes and paddocks
- Runs up to 100 metres per sprinkler
- Maintenance is low due to a lack of moving parts
- Polythene pipes are durable

**Disadvantages**
- More effort to gain even distribution uniformity
- Need a motor bike to shift sprinklers quickly
- Labour requirements are high
- Needs to be shifted before paddock can be slashed

**Side roll**

**Advantages**
- Distribution is affected by wind
- Medium pressure system
- Moderate labour requirement

**Disadvantages**
- Requires flat ground with no obstacles
- Regular shaped paddock required

**Hand shift**

**Advantages**
- Adaptable to irregular paddocks
- Medium pressure system
- Low capital costs

**Disadvantages**
- Labour intensive
- Not suited to tall crops
• Limited length

**Solid set**

**Advantages**
- Can be used in irregular shaped paddocks
- Very low labour requirements
- Easy and inexpensive to automate

**Disadvantages**
- High initial outlay
- Limits methods of ground preparation and harvesting
- Thought needs to be put into planning of the system in relation to supporting the sprinkler heads to avoid damage from cows

**Low pressure boom**

**Advantages**
- Low pressure – reduced pumping costs
- Reasonably even distribution

**Disadvantages**
- Medium labour input
- Frictional head losses in hose versions
- Requires a flat paddock with no obstructions

**Notes**
- Be aware of speed of travel systems and how they measure incoming tow lines

**Surface irrigation (flood)**

**Advantages**
- Cover large areas quickly
- Low operating costs

**Disadvantages**
- Need level paddocks
- Not very water efficient
- High labour cost
- Unsuitable for sandy soils
- Very high flow rates required

**Sub-surface drip**

**Advantages**
- Differing lateral configurations depending upon crop
- Low pressure and output
- Small frequent irrigations

**Disadvantages**
- Suits permanent crop
- May require an overhead system for germination
- Cannot be moved from paddock to paddock
- Flush system and maintenance needed on a regular basis

*Acknowledgements: Irrigation for Dairying, DPI, Waters, Swan, Lake 1995.*
Module 7 – Irrigation equipment audit

The 10 minute irrigation performance checklist

Irrigation is the single biggest factor influencing farm production. How well is your irrigation performing? Circle one answer for each question and then add them together.

Q1 Do you have enough water for your crop or pasture area?
   1  Don’t know
   2  Inadequate volume
   3  Adequate in average year
   4  Adequate in all years

Q2 Can you deliver enough water to meet the peak crop/pasture water requirement?
   1  Don’t know
   2  Inadequate rate of supply
   3  Adequate in average year
   4  Adequate in all years

Q3 Do you have a strategy in place for managing periods of limited water availability?
   1  No plan
   2  Limited consideration
   3  Some consideration
   4  Detailed strategy

Q4 How efficient is your on-farm storage and distribution system(s)?
   1  Don’t know
   2  Okay
   3  Good
   4  Excellent

Q5 Is your application system(s) operating at the design pressure in the field?
   1  Don’t know
   2  No
   3  Yes, in some areas
   4  Yes, in all areas

Q6 How evenly does your system apply water within the field?
   1  Don’t know
   2  Large variations
   3  Some variations
   4  Only minor variations
Q7 Do you know the rate of water applied by your system (i.e. mm/hr or L/hr)?
1. Don’t know
2. Based on dealer info only
3. Measured some time ago
4. Measured routinely

Q8 What is the current physical condition of your pumping, storage, distribution and application system(s)?
1. Don’t know
2. Major repairs required
3. Minor repairs required
4. No repairs required

Q9 Do you measure, record and compare (i.e. benchmark) crop yield/quality/returns and the volume of water applied?
1. Not measured
2. At farm level only
3. Sometimes at field level
4. Routinely at field level

Q10 Do you use an irrigation-scheduling tool to modify irrigation applications?
1. No
2. Subjective tool only
3. Objective tool sometimes
4. Objective tool regularly

Q11 How well do you match your irrigation interval and volume applied with the crop/pasture requirements and soil limitations?
1. Don’t know
2. Poorly matched
3. Sometimes well matched
4. Always well matched

Q12 Do you modify your irrigation application in response to weather conditions?
1. No
2. Sometimes
3. Usually
4. Always
Q13 Are you experiencing crop/pasture or irrigation problems associated with soil structural degradation?
1  Don’t know
2  Moderate Effect
3  Minor Effect
4  No Effect

Q14 Is the depth to your ground water table changing due to irrigation practices?
1  Don’t know
2  Significant change
3  Minor change
4  No change

Q15 What is the quality of water used for irrigation?
1  Don’t know
2  Marginal
3  Satisfactory
4  Good

Once you have added your scores from each question, use the table below to identify the opportunity for you to improve performance and profitability. Use your low scores to identify possible priority areas to target for irrigation benefits.

<table>
<thead>
<tr>
<th>Total Score</th>
<th>Opportunity to improve irrigation performance</th>
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<tbody>
<tr>
<td>15 – 30</td>
<td>Large</td>
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<tr>
<td>31 – 45</td>
<td>Significant</td>
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<td>46 - 60</td>
<td>Minor</td>
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</tbody>
</table>
Rules of thumb

- 1m head of water = 1.5 psi
- multiply L/s by 800 to get GPH
- 1 psi = 6.88 KPA
- 1L of water spread over 1m² = 1mm
- 1ML spread over 1 ha = 100mm (4 inch)
- 1ML over 10 acres = 1 inch
- 1.08 Big Gun nozzle at 60 psi applies 1ML in 22 hours
- 1mm applied to 1ha = 10,000 litres
- Most soils store 60mm of Readily Available Water per metre of root depth
- ET (evapo-transpiration) values can range from 2.0mm on a cloudy day to 14mm on a hot windy day

Guide to irrigation system operating pressures:

<table>
<thead>
<tr>
<th>Irrigation System</th>
<th>Range of Operating Pressures</th>
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</thead>
<tbody>
<tr>
<td>Drip and Trickle Systems</td>
<td>7 – 15 psi</td>
</tr>
<tr>
<td>Solid Set Sprinklers</td>
<td>40 – 50 psi</td>
</tr>
<tr>
<td>Centre Pivot and Laterals</td>
<td>6 – 30 psi</td>
</tr>
<tr>
<td>Travelling Gun Irrigators</td>
<td>70 – 90 psi</td>
</tr>
</tbody>
</table>
## Appendix

### Solid set – catch can record sheet

<table>
<thead>
<tr>
<th>Type:</th>
<th>Solid Set</th>
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<tbody>
<tr>
<td>Name:</td>
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</table>

Sprinkler Spacing (m):
Lateral Spacing (m):

Catch Can Spacing Along Lateral (m):
Catch Can Spacing Between Lateral (m):
Catch Can Diameter (mm):

Can Grid Size:
  Along Lateral -
  Between Laterals -

**Volume Applied Grid (ml):**

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<tr>
<th>Can no.</th>
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<th>Dist. (m)</th>
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</table>

Run Time (min):

Av. Dep (mm/hr):
Max Dep (mm/hr):
DU (%):
Mix Dep (mm/hr):
CU (%):
# Hand shift – catch can record sheet

<table>
<thead>
<tr>
<th>Type:</th>
<th>Hand Shift</th>
<th>Run Time (min):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td></td>
<td></td>
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</tbody>
</table>

- Sprinkler Spacing (m):
- Spray Line Spacing (m):
- Catch Can Spacing Along Lateral (m):
- Catch Can Spacing Between Lateral (m):
- Catch Can Diameter (mm):

**Can Grid Size:**
- Along Lateral (Between 3 sprinklers) -
- Between Laterals -

**Right Hand Side Grid (ml):**

<table>
<thead>
<tr>
<th>Can no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
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</thead>
<tbody>
<tr>
<td>Dist. (m)</td>
<td>6</td>
<td>5</td>
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<td>3</td>
<td>2</td>
<td>1</td>
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</tbody>
</table>

**Left Hand Side Grid (ml):**

<table>
<thead>
<tr>
<th>Can no.</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
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<th>3</th>
<th>2</th>
<th>1</th>
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</thead>
<tbody>
<tr>
<td>Dist. (m)</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
## Traveller – catch can record sheet

<table>
<thead>
<tr>
<th>Type:</th>
<th>Traveller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td></td>
</tr>
<tr>
<td>Sprinkler Wetted Diameter (m):</td>
<td></td>
</tr>
<tr>
<td>Gun Arc Angle (degrees):</td>
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<tr>
<td>Distance Travelled (m):</td>
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<tr>
<td>Run Time (min):</td>
<td></td>
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<tr>
<td>Lane Spacing (m):</td>
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<tr>
<td>Avg. Depth (mm):</td>
<td>DU (%)</td>
</tr>
<tr>
<td>Catch Can Spacing (m):</td>
<td>CU (%)</td>
</tr>
<tr>
<td>Catch Can Diameter (mm):</td>
<td>Speed (m/hr):</td>
</tr>
<tr>
<td>Max. Depth (mm):</td>
<td>Min. Depth (mm):</td>
</tr>
<tr>
<td>Wetted Diam. (m):</td>
<td>M.A.R (mm/hr):</td>
</tr>
<tr>
<td>No. Cans Between Tow Path:</td>
<td></td>
</tr>
</tbody>
</table>

### Right Side Hand Side of Tow Path:
- Can No.: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
- Distance From Tow Path (m):
- Volume Applied (ml):
- RHS Depth Applied (mm):

### Left Hand Side of Tow Path:
- Can No.: 40 39 38 37 36 35 34 33 32 31 30 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
- Distance From Tow Path (m):
- Volume Applied (ml):
- LHS Depth Applied (mm):

### Distance from Tow Path (m):
- Volume Applied with Overlap (ml):
- Depth Applied with Overlap (mm):
# Centre pivot – catch can record sheet

<table>
<thead>
<tr>
<th>Can No.</th>
<th>Distance from centre (m)</th>
<th>Volume Applied (ml)</th>
<th>Depth Applied (mm)</th>
<th>Span Length (m)</th>
<th>Sprinkler Wetted Radius (m)</th>
<th>Last Sprinkler / End Gun Wetted Radius (m)</th>
<th>Distance Travelled (m)</th>
<th>Run Time (min)</th>
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</thead>
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<td></td>
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<tr>
<td>34</td>
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<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Catch Can Spacing (m):**
- **Catch Can Diameter (mm):**
- **Distance To First Can From Centre (m):**
- **No. of Cans:**

**Appendix**
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1 Client Details

Client Name:
Dairy enterprise name:
Dairy enterprise locality:
Lot on Plans:

2 Site Visit Details

Conducted by: Ross Warren & John Miller
Date Evaluation Conducted:
Report Compiled by: Ross Warren

3 Property Description

<table>
<thead>
<tr>
<th>General</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Property location</td>
<td></td>
</tr>
<tr>
<td>Lot on plans</td>
<td></td>
</tr>
<tr>
<td>Farm area (ha)</td>
<td></td>
</tr>
<tr>
<td>Annual average rainfall</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Land use</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Dairying Area</td>
<td></td>
</tr>
<tr>
<td>Pasture area and types</td>
<td>Rhodes grass, Panic</td>
</tr>
<tr>
<td>Cropping area and types</td>
<td>Cow pea, oats</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Irrigation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water allocation</td>
<td></td>
</tr>
<tr>
<td>Water Source</td>
<td></td>
</tr>
<tr>
<td>Irrigation Water Used</td>
<td>100 ML approx</td>
</tr>
<tr>
<td>Irrigation Area (ha)</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Herd Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total stock numbers</td>
<td></td>
</tr>
<tr>
<td>Total average annual milking herd</td>
<td></td>
</tr>
<tr>
<td>Average annual milk production</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feeding system</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td></td>
</tr>
</tbody>
</table>

4 System Upgrade

The family have made a significant upgrade of the irrigation system at the property. When purchased there was a network of hand shift, operated by a diesel motor. After consultation with Ross and John and past experience with solid set at the home farm, the new system was installed.
4.1 Previous System

The previous system was hand shift pipes. These were laborious, leaking and generally difficult to manage.

4.1.1 Irrigation System Performance

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 1 Results from IPART Report</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution of Uniformity (%)</td>
<td>61.55</td>
<td></td>
</tr>
<tr>
<td>Coefficient of Uniformity (%)</td>
<td>78.56</td>
<td></td>
</tr>
<tr>
<td>Minimum Depth Applied (mm)</td>
<td>2.12</td>
<td></td>
</tr>
<tr>
<td>Maximum Depth Applied (mm)</td>
<td>11.88</td>
<td></td>
</tr>
<tr>
<td>Average Depth Applied (mm)</td>
<td>8.66</td>
<td></td>
</tr>
<tr>
<td>Average Depth Applied in Lowest Quarter (mm)</td>
<td>5.33</td>
<td></td>
</tr>
</tbody>
</table>

SOLID SET (before nozzle upgrade)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution of Uniformity (%)</td>
<td>39.51</td>
<td></td>
</tr>
<tr>
<td>Coefficient of Uniformity (%)</td>
<td>60.92</td>
<td></td>
</tr>
<tr>
<td>Minimum Depth Applied (mm)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Maximum Depth Applied (mm) | 0.06  
---|---  
Average Depth Applied (mm) | 0.02  
Average Depth Applied in Lowest Quarter (mm) | 0.01  

4.1.2 **Irrigation Pump Performance**

The pump was an aged with a belt drive diesel motor attached. These results are depicted below. It should also be noted that the new solid set was tested on the 12th August. The system didn’t perform to our expectations, after consideration we advised the nozzle size be increased and operating pressure also. The pump performance for the initial test is listed below.

**Table 2 Pump System Performance**

<table>
<thead>
<tr>
<th>Pump Make &amp; Type</th>
<th>TLOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate (lps)</td>
<td>30</td>
</tr>
<tr>
<td>Pressure (kPa)</td>
<td>275</td>
</tr>
<tr>
<td>Pump Efficiency (%)</td>
<td>NA</td>
</tr>
<tr>
<td>Motor Efficiency (%)</td>
<td>NA</td>
</tr>
<tr>
<td>Overall efficiency (motor &amp; pump %)</td>
<td>10.4</td>
</tr>
<tr>
<td>Actual kW/ML/m.hd</td>
<td>8.4</td>
</tr>
<tr>
<td>Actual kWh/h</td>
<td>20L diesel/hr</td>
</tr>
<tr>
<td>Actual kWh/ML</td>
<td>616</td>
</tr>
</tbody>
</table>

**SOLID SET PUMP (before nozzle upgrade)**

<table>
<thead>
<tr>
<th>Pump Make &amp; Type</th>
<th>Southern Cross, 80x50-200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate (lps)</td>
<td>24</td>
</tr>
<tr>
<td>Pressure (kPa)</td>
<td>275</td>
</tr>
<tr>
<td>Pump Efficiency (%)</td>
<td>42.4</td>
</tr>
<tr>
<td>Motor Efficiency (%)</td>
<td>90</td>
</tr>
<tr>
<td>Overall efficiency (motor &amp; pump %)</td>
<td>36.25</td>
</tr>
<tr>
<td>Actual kW/ML/m.hd</td>
<td>7.5</td>
</tr>
<tr>
<td>Actual kWh/h</td>
<td>21</td>
</tr>
<tr>
<td>Actual kWh/ML</td>
<td>243</td>
</tr>
</tbody>
</table>

4.2 **New Irrigation System**

A system assessment was conducted by Ross Warren & John Miller on 02/09/11. The results from this system assessment are shown in the following table. Farmer
installed new nozzles as recommended and the sprinklers operating were reduced to reach the desired pressure. It was pleasing to realise significant gains in pump and irrigation performance.

4.2.1 Irrigation System Performance

Table 3 Results from IPART Report

<table>
<thead>
<tr>
<th>Distribution of Uniformity (%)</th>
<th>83.33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of Uniformity (%)</td>
<td>88.65</td>
</tr>
<tr>
<td>Minimum Depth Applied (mm)</td>
<td>2.36</td>
</tr>
<tr>
<td>Maximum Depth Applied (mm)</td>
<td>5.85</td>
</tr>
<tr>
<td>Average Depth Applied (mm)</td>
<td>3.72</td>
</tr>
<tr>
<td>Average Depth Applied in Lowest Quarter (mm)</td>
<td>3.10</td>
</tr>
</tbody>
</table>

The results of this system are outstanding.

4.2.2 Irrigation Pump Performance

Table 4 Pump System Performance

<table>
<thead>
<tr>
<th>Pump Make &amp; Type</th>
<th>Southern Cross, 80x50-200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate (lps)</td>
<td>26</td>
</tr>
<tr>
<td>Pressure (kPa)</td>
<td>413</td>
</tr>
<tr>
<td>Pump Efficiency (%)</td>
<td>70.27</td>
</tr>
<tr>
<td>Motor Efficiency (%)</td>
<td>90</td>
</tr>
<tr>
<td>Overall efficiency (motor &amp; pump %)</td>
<td>60.08</td>
</tr>
<tr>
<td>Actual kW/ML/m hd</td>
<td>4.55</td>
</tr>
<tr>
<td>Actual kWh/h</td>
<td>20.95</td>
</tr>
<tr>
<td>Actual kWh/ML</td>
<td>223</td>
</tr>
</tbody>
</table>

4.3 Results of System Upgrade

The results from the system upgrade are summarised in the below Star rating table.

Table 5 Star Rating Table - System Performance

<table>
<thead>
<tr>
<th></th>
<th>Target</th>
<th>Existing system</th>
<th>Result</th>
<th>Star rating (5 star best result)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CU%</td>
<td>80</td>
<td>78.56</td>
<td>88.65</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Power (kW/ML/m hd)</td>
<td>5</td>
<td>8.4</td>
<td>4.55</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Labour</td>
<td>1hr per shift</td>
<td>0.88ha – 0.2hr</td>
<td></td>
<td>★★★★★☆</td>
</tr>
<tr>
<td>Forage</td>
<td>Increase by 1t DM/ha/yr</td>
<td>Est. increase 3t/ha/yr</td>
<td></td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Pump efficiency</td>
<td>70%</td>
<td>(Overall 41.6%)</td>
<td>70.27</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Water use (%) reduction</td>
<td>10</td>
<td></td>
<td>10</td>
<td>★★★★★★</td>
</tr>
</tbody>
</table>
*Note: pump efficiency has been calculated manually if IPERT has program errors.

**Note: water use comparisons are between a hand shift and solid set

**Table 6 Outline of Star Rating System (power rating in increments of 2.5 not %)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 star</td>
<td>★★★★★ – exceeds target</td>
</tr>
<tr>
<td>4 star</td>
<td>★★★ – 5% below target</td>
</tr>
<tr>
<td>3 star</td>
<td>★★★ – 10% below target</td>
</tr>
<tr>
<td>2 star</td>
<td>★★ – 15% below target</td>
</tr>
<tr>
<td>1 star</td>
<td>★ – 20% below target</td>
</tr>
</tbody>
</table>

There was a noticeable improvement from the hand shift to the solid set. It is interesting to note the marked improvement in the solid set when the new nozzles were installed and pressure increased.

4.3.1 Efficiency Achievement Grant

**Table 7 Efficiency Achievement Grant Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Target</th>
<th>Result</th>
<th>Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Use Efficiency – Solid Set</td>
<td>80% CU</td>
<td>88.65%</td>
<td>Yes</td>
</tr>
<tr>
<td>Energy Use Efficiency</td>
<td>25% reduction</td>
<td>46%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

4.4 Recommendations

The new solid set is working to expectations. Farmer has installed the system according to the DFWP recommendations, the lateral and sprinkler spacing’s are at the desired specifications. The new system is greatly improved on the old hand shift. A larger area is covered in one irrigation event, using less power, water and labour. Much more feed will be grown under the new irrigation plant, it would be expected an increase of over 3t/ha would be achieved.

The results clearly demonstrate the effect of the changed nozzles and pressure in terms of irrigation performance. Following the recommendations was clearly justified.

5 Attachments

<IPART REPORT>
<IPERT REPORT>