



## Centre Pivot System Capacity

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*'System Capacity' is the most important design criterion for centre pivots. In the past many systems were under-designed to minimise cost and were not able to match peak crop water requirements. This has been the single main reason for centre pivot failure.*

### What is "system capacity"?

The system capacity of a centre pivot is the rate at which water can be supplied to the irrigated area, normally expressed in **mm/d** – typically between 8 and 20 mm/d.

It is the main criterion that the pump, pipes and sprinkler design is based on, and for a given pivot can be calculated as follows:

$$\text{System capacity} = \frac{\text{pump flowrate (ML/d)} \times 100}{\text{area irrigated (ha)}} \text{ mm/d}$$

**Example:** a 400 m long centre pivot irrigates 50 ha. With a pump flow rate of 6ML/d, it has a system capacity of:

$$\frac{6 \text{ ML/d} \times 100}{50 \text{ ha}} = 12 \text{ mm/d}$$

The *desired* system capacity depends on the water requirement of your crop, the application efficiency and the operating hours of the system – these are discussed below. Given the desired system capacity, the designer can calculate required flow rate and design the system.

If the system capacity is too low, the system may not be able to supply enough water over a hot spell. A conservative system capacity ensures that the irrigation requirements can be met comfortably, even under extreme climatic conditions. However, the investment costs would be higher (larger pipes, pumps and/or pressure) than for a lower system capacity. Also, a higher capacity machine is more likely to have excessive application rates at the outer end of the pivot.

### Application depth

The depth of water actually applied in an irrigation pass depends on the system capacity of the pivot *and* the speed the machine is set to rotate at.

**Example:** a 12 mm/d pivot completing its circle in 24 hours applies 12 mm; if it completes the circle in 48 hours it applies 24 mm.



*Figure 1 How much the system can apply is crucial*

**To determine a suitable system capacity, the following must be considered:**

**Application efficiency (AE)** – the proportion of the applied water that the crop can use. For a modern, well-designed machine we can assume at least **90 % AE**. Under "normal" conditions (no wind, low evaporation - such as at night), the AE may be 95% or higher. 90 % is a conservative AE to assume, but may be appropriate under peak crop water requirement conditions.

**Operating hours** – the *Pumping utilisation ratio* (PUR) is the proportion of time that the machine needs to operate to supply the peak crop water requirement. Continuous operation over many days should not be relied upon because breakdowns, power blackouts and other down-time will occur occasionally. The recommended maximum PUR of **0.85** is equivalent to operating for 6 days in 7, or 20 hours in 24. For most of the time when crop water use is less than the peak requirement, shorter operating times are needed.

A lower PUR may be desirable if operation primarily on off-peak electricity is planned (off-peak electricity hours of 88 hours per week is a PUR of 0.52), or where a more conservative operating regime is desired. A conservative PUR requires a higher system capacity (and capital cost) but gives more flexibility to manage extreme events and down-time.

### Peak crop water requirement

This is the highest rate of crop water use, usually expressed in mm/d. The peak water requirement is crop dependent. For perennial pasture, water use is equal to the measured evapotranspiration (ET<sub>o</sub>), less rainfall. ET<sub>o</sub> is similar to evaporation measured in an evaporation pan (E<sub>pan</sub>), but is not the same. At Tatura;

$$\text{Perennial pasture water use} = ET_o = 0.85 E_{pan}$$

The peak pasture water requirement used in calculating system capacity is not the highest daily ET<sub>o</sub>, but is the highest average daily ET<sub>o</sub> likely to occur over several days. Three days is generally considered to be an appropriate interval.

The frequency at which a particular 3-day average daily ET<sub>o</sub> recurs is a means of calculating the risk that a particular system capacity will not be able to supply enough water. Figure 2 shows the frequency that peak 3-day ET<sub>o</sub> events occur at Tatura.

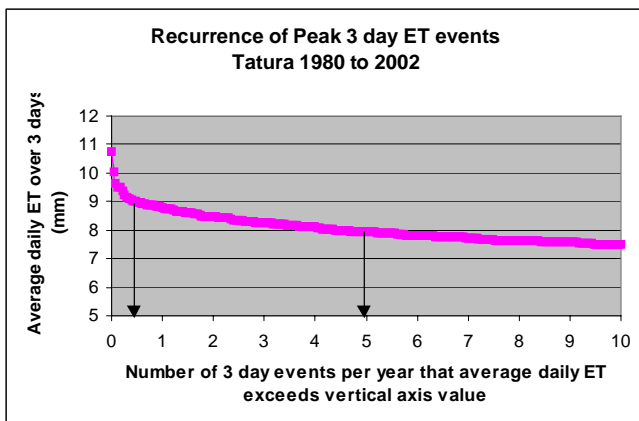


Figure 2 Peak evapotranspiration events

From Figure 2, 8 mm of average daily ET<sub>o</sub> over 3 days (24 mm total over 3 days) is exceeded 5 times in a typical year. However, 9 mm of average daily ET<sub>o</sub> over three days is exceeded approximately 0.5 times a year (once each 2 years) at Tatura. That is, a system able to apply 8 mm/d is not able to keep up with crop water demand on several occasions in a typical season, where 9 mm/d is rarely exceeded.

The 3-day average ET<sub>o</sub> of **9 mm/day** is recommended as the peak pasture water requirement to be assumed for system capacity selection at Tatura.

The **desired** system capacity can then be calculated as follows:

$$\text{System capacity} = \frac{\text{peak crop water requirement}}{AE \times PUR} \text{ mm/d}$$

For the Tatura example with peak crop water requirement of 9 mm/d, an application efficiency of 0.9 and a pumping utilisation ratio of 0.85, the desired minimum system capacity will be 12 mm/d:

$$\text{System capacity} = \frac{9 \text{ mm/d}}{0.9 \times 0.85} = 11.8 (\cong 12) \text{ mm/d}$$

**Thus, the recommended minimum system capacity for perennial pasture at Tatura is 12 mm/d.**

A higher system capacity may be preferable, but would require a higher capital cost.

Having a lower system capacity does not necessarily mean pasture will die in hot weather. Operating a lower system capacity system continuously can maintain soil moisture levels. However, *if the system capacity is lower than the peak water requirement, in times of peak crop water use, the crop will be extracting water from the soil faster than the pivot can replace it, even when operating continuously.* If the pivot then breaks down, it can be very difficult to catch up the required soil moisture levels for optimal production.

With a pivot, farmers typically aim to irrigate after 20 to 25 mm of pasture water use (ET<sub>o</sub>) has occurred (25 to 30 mm E<sub>pan</sub>-R). previous research suggest that if the soil moisture deficit on typical SIR soils increases to 35 to 40 mm, pasture growth slows, and wilting may occur (Wood and Finger 2006).

A pivot with a marginal system capacity requires a high level of management to avoid productivity loss, and major crop losses could occur with a breakdown or power outage. A more conservative (higher) system capacity gives additional security for limited additional capital cost.

### System capacity and operating hours

While the system capacity is critical to supply the peak crop water requirement, it also determines the operating hours necessary in “normal” conditions.

Figure 3 shows the operating hours required for a range of system capacities and daily ET<sub>o</sub> conditions.

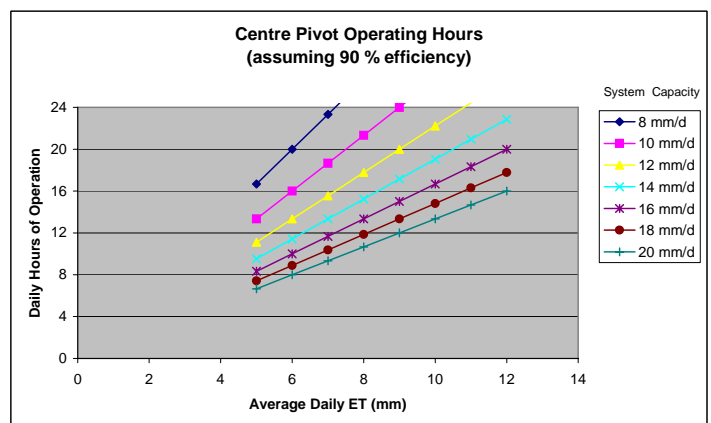


Figure 3 Operating hours and system capacity

Low system capacity machines (10 mm/d or less) need to operate continuously to maintain (or minimise the decline of) soil moisture levels in peak demand times, and need to operate for long periods in “normal” summer conditions.

Higher system capacity machines can cope with peak demands much more readily, and are more flexible in normal conditions, allowing most pumping to be carried out within periods of cheaper off-peak electricity rates.

**A conservative system capacity allows more flexibility of operation, and more security.**

## Reference

Wood, ML and Finger, L (2006). Influence of irrigation methods on water use and production of perennial pastures in northern Victoria. Australian Journal of Experimental Agriculture 46, 1605-1614.

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