Managing Wheel-Lines and Hand-Lines for High Profitability

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS044E

In 2008, there were nearly 3 million acres in the United States being irrigated by wheel-lines or hand-lines, with 1.3 million of these acres in the Pacific Northwest. Currently there are publications that describe wheel-lines and how they work (Hill 2000), as well as how to maintain them (Beard et al. 2000). However, there are very few publications providing practical advice on managing wheel- and hand-lines. The focus of this publication then is on providing background information to assist managers of wheel- or hand-lines in understanding soil water management and on offering some best management practices that lead to higher profitability and improved environmental water quality.

Soil Water Basics

Water is held in the empty spaces between soil particles. When these empty spaces are completely filled, the soil is said to be saturated (mud). Excess water will drain out over time. This will continue until a point where the soil can hold a certain amount of water (indefinitely) against the downward pull of gravity. This soil water content is called field capacity.

As a plant's roots remove water from the soil, the soil dries out to the point where the suction or pull of the soil on the water is greater than the plant's ability to absorb water. At this point, the plant will wilt and die. This soil water content is referred to as the permanent wilting point. The difference between field capacity and permanent wilting point is known as the available water-holding capacity (AWC) of the soil (Figure 1).

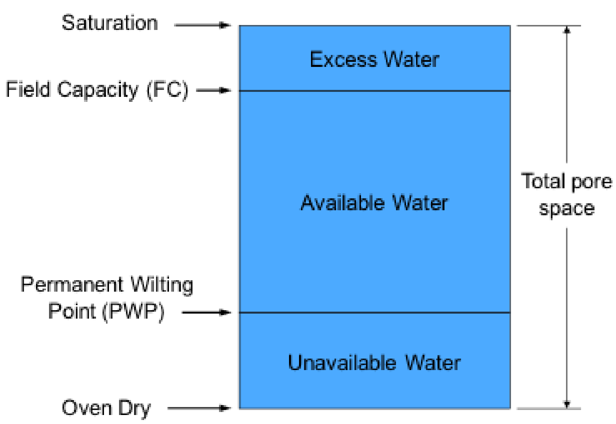

Figure 1. The different levels of soil water content.

Different soils have different available water-holding capacities (Table 1). Sand cannot hold much water compared to silt or clay. A plant's rooting depth is also an important consideration: a plant with deeper roots, such as alfalfa, has access to much more soil and, consequently, has a larger reservoir of soil water to draw upon compared to plants with shallower roots, such as onions or potatoes.

Table 1. Typical water-holding capacity ranges for various soil textures. (NCAT 2009)

Soil Texture	Available Water (AW) in/ft
Coarse Sand	0.2–0.8
Fine Sand	0.7–1.0
Loamy Sand	0.8–1.3
Sandy Loam	1.1–1.6
Fine Sandy Loam	1.2–2.0
Silt Loam	1.8–2.5
Silty Clay Loam	1.6–1.9
Silty Clay	1.5–2.0
Clay	1.3–1.8
Peat Mucks	1.9–2.9

It is important to note that plants grown in sandy soils use the same amount of water and nutrients as those grown in heavier soils. Sandy soils do not need more water; they just need to be irrigated more often but in smaller amounts, since this soil cannot retain as much water as heavier soils. Applying more water than a soil can retain results in deep percolation (water leached past the root zone of the plant), which wastes water, pumping energy, and vital plant nutrients that are held in the soil water solution.

As the soil water content is drawn down from field capacity (100% of available water) to permanent wilting point (0% of available water), production is generally unaffected until a point where production drops off (Figure 2). This point is commonly chosen as the Management Allowable Deficit (MAD). The shape of the curve and, therefore, the location of the MAD point vary for different plants. Soil water depletion below the MAD point will result in significant yield losses.

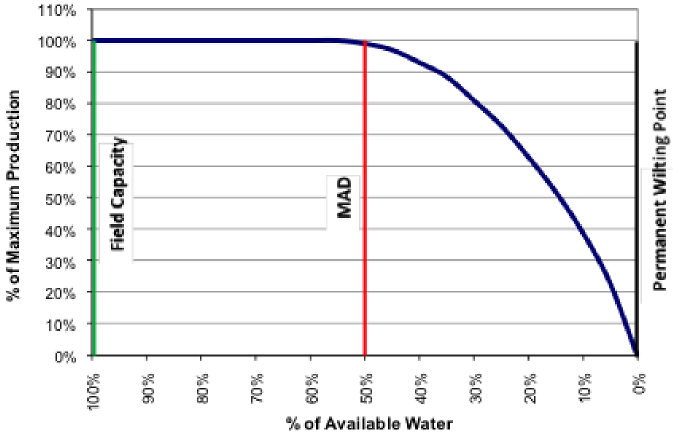

Figure 2. A generalized curve shape showing how plant production (growth) is affected by soil water stress.

Limitations of Set-Move Systems

Wheel-lines, and especially hand-lines, require considerable time and effort to move from one set to another. Consequently, growers prefer to use longer set times because this involves the least amount of work. Therefore, 24-hour sets are common. This often results in large amounts of water being applied with long intervals between irrigations (typically about 3 inches in a 24 hour set). This is acceptable if the soil is capable of holding these large amounts of water. However, not all soils can hold this much water in the root zone, and much of the water would be lost to deep percolation, or the crop would have to go into the stress zone (Figure 2) in order to use that much water. Here is an example of soil water budgeting for pasture grass on a sandy soil:

If we assume the rooting depth of pasture grass is 3 ft and that the soil water-holding capacity of the loamy sand soil is 1.2 in/ft (Table 1), then the total water-holding capacity is 1.2 in/ft x 3 ft or 3.6 in. of water that can be held in the root zone. However, we do not want to fully deplete the soil water because below about 50% of the available water, there will be significant yield losses (Figure 2). If we choose a MAD of 50%, then 3.6 in. of water x 50% is 1.8 in. of water, which is the most soil water that can be depleted before irrigation is needed to refill the root zone. If we use the typical situation described above, where 3 in. of water is deposited in 24 hours, then almost half of the water would be wasted (applying 3 in. when soil can only hold 1.8 in if irrigated before MAD point). In this case, 12 hour sets should be chosen to apply half as much water (1.5 in.), which is less than the calculated 1.8 in. maximum soil water depletion point. However, if the same grower had a field of alfalfa (5 ft deep root zone) on a silt loam soil (2 in/ft water-holding capacity), then 24 hour sets would work fine (5 ft x 2 in/ft = 10 in. of available water). This 10 in. of available water multiplied by the 50% MAD results in 5 in. of maximum depletion (3 in. application less than 5 in.). In fact, in this case, the grower may actually be able to move to 36 hour sets (4.5 in application per set).

Movement Patterns

There are three general patterns for moving wheel-lines or hand-lines. These patterns are commonly called TAXI, WIPE, and SKIP.

TAXI: In the TAXI pattern, farmers irrigate every riser down to the end of the field, (risers 1–14 sequentially) (Figure 3), then taxi the empty system all the way back to the original location (riser 1) before starting the cycle over.

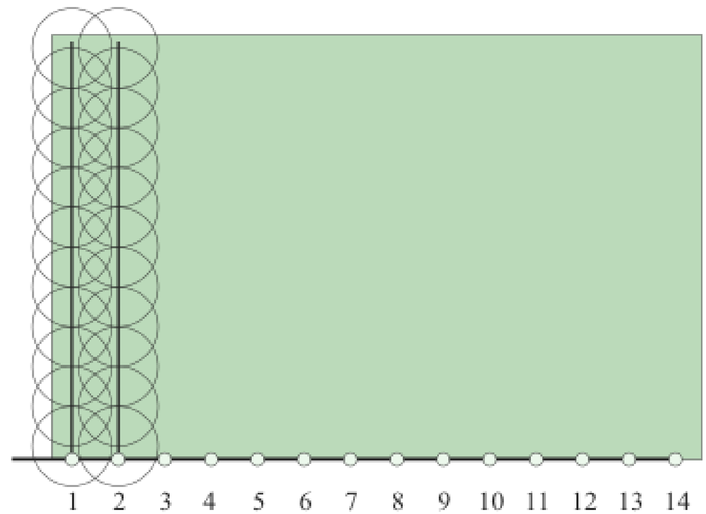

Figure 3. Typical overlap patterns and movement plan for a wheel-line or hand-line system.

TAXI is a viable option but is often unpopular because moving an empty system all the way back to the beginning is labor-intensive. (Typically, hand-lines are loaded onto a trailer and hauled back to the riser 1 position before recommencing the irrigation cycle.)

WIPE: In the WIPE pattern, farmers irrigate every riser in one direction (risers 1–14 in Figure 3), then wait a short time (e.g., 12–24 hours) before irrigating in the opposite direction (risers 14–1 in Figure 3). This pattern eliminates the need to move the empty system all the way back across the field. Although it requires less total movement of the irrigation pipelines, the WIPE pattern usually results in too much water being applied at the ends of the field within a short time interval, resulting in water and nutrient loss to leaching. Using this pattern also results in a very long time interval between irrigations on the field ends, during which the plants see significant water stress and yield loss. Consequently, this option is not recommended.

SKIP: In the SKIP pattern, farmers irrigate every other riser down, then irrigate the missed risers on the way back (1-14 as numbered in Figure 4).

The SKIP pattern is recommended for the following reasons:

1. It avoids the WIPE problems of overwatering and long, dry intervals at the field ends.
2. Although it involves the same total movement of lines as TAXI, this labor is spread out into regular intervals making labor easier to plan for and manage.

3. Because the sprinklers will not overlap on irrigated soil from the previous irrigation set (no overlap between sets 1 and 2 in Figure 4 as there is in Figure 3), the application depths in these areas are actually less. This results in the equivalent of more frequent irrigations with smaller amounts of water in these overlap regions. Because of this, there is less likelihood of water stress between irrigations or of exceeding the water-holding capacity of the soil and the consequent loss of water and nutrients to deep percolation and/or runoff. This will result in higher yields and better crop quality compared to the TAXI and WIPE options.

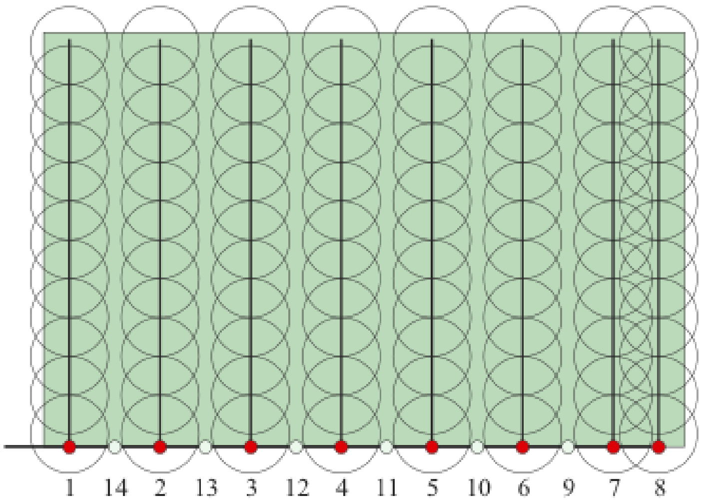

Figure 4. SKIP move pattern. Irrigate every other riser down the field (red), then irrigate the missed risers (white) on the way back (riser 1–14 in order as labeled).

When using the SKIP movement pattern, painting every other riser a different color may help irrigators remember which riser they should be on.

Application Uniformity

Uniformity in irrigation water application is necessary to ensure maximum production for all areas of the field. However, sprinklers do not apply water in a perfectly uniform way. To compensate for poor uniformity, the irrigation manager will need to apply more total water to adequately irrigate all areas of the field, or the crop will suffer water stress in these low water areas.

Irrigation application uniformity can be improved over multiple irrigation cycles by using offsets. With this practice, the move position is offset by 20–30 ft (one roll of a 7 ft wheel or 2 rolls of a 5 ft wheel) to the right or left of the riser position (Figure 5). An offset can be made for hand-lines using a 30 ft length of pipe or 50% of the riser spacing and an elbow that are moved from riser to riser along the mainline. This offset is held through the entire course of that irrigation cycle (all risers). The next cycle should be offset to the other side of the riser or set at the riser itself. The effect of averaging application depths from the shifted position pattern can markedly improve application uniformity. This improvement is particularly noticeable if operation pressures are on the low side or if a constant day–night, diurnal wind pattern is present. In the case of extreme diurnal wind patterns, an offset of 12 hours in the start time in successive irrigations may also be desirable.

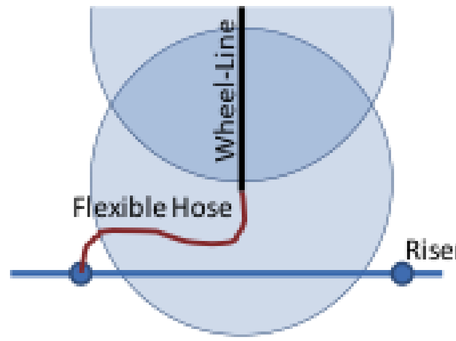

Figure 5. Using an offset on every other irrigation cycle can significantly improve application uniformity.

Move Frequency

Shallow soils (over bedrock) and sandier soils cannot hold very much water. Watering for long intervals (24 hour sets) will often apply more water than these soils can retain in the root zone, and this water will be lost to deep percolation—taking the soil's soluble nutrients with it. In these cases, the irrigation manager has two choices: using a shorter move interval (8 or 12 hour sets), or using smaller nozzles, which will result in a lower application rate. If less water is applied due to smaller nozzle sizes, an additional wheel- or hand- line may have to be purchased and run simultaneously in the field to keep up with the crop water-use rates.

Remember, do not apply more water than the soil can hold in the plant root zone.

Additional Management Recommendations

Significant amounts of water can be lost to leaks. In a few tests, leaks were measured on wheel-lines in growers' fields, and most growers were surprised at the rate of water loss. Even though the leaks appeared minor, many had as much water escaping as 2–5 sprinkler heads. It is a good practice to plan some time at regular intervals throughout the season to check the system, fix leaks, and replace gaskets.

Sprinkler Heads

Brass impact sprinkler heads are the most commonly used in agricultural production (Figure 6). The base or pivoting point of these sprinkler heads is usually the first to fail and can result in sprinklers that no longer pivot, even though the impact arm still functions and appears normal from a distance. A non-rotating sprinkler head leads to very poor uniformity, overwatering in highly localized spots, and significant water stress in other areas under the sprinkler. It is important to watch the line operate for a minute to ensure that each sprinkler head is actually rotating. Plastic ¾ in. impact sprinklers tend to wear out very quickly and often do not stand up well to the many hours of use required of an agricultural sprinkler. Newer ¾ in. rotating sprinklers have recently come on the market (Figure 6), and preliminary tests are good for throw distance and uniformity. Although these sprinklers look promising, their robustness and longevity have not yet been validated by large numbers of growers.

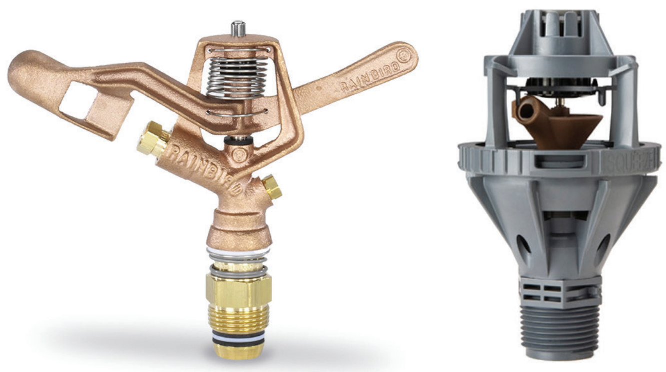

Figure 6. A ¾ in. brass impact sprinkler and a newer ¾ in. rotating style sprinkler, both designed for agricultural use.

Sprinkler nozzles are key to metering how much water is applied. They are also subject to the highest water velocities and wear out over time. This is especially true when the irrigation water is dirty or contains sand or other abrasive materials. As they wear out, the nozzle diameter gets larger and more water is applied than was originally planned. This results in poor system uniformity. A brass nozzle diameter can be easily verified by inserting a similarly sized drill bit and testing the looseness of the fit. Checking the nozzle size, at least seasonally, is a good management practice. Replacement sprinkler nozzles are inexpensive, and growers should plan to replace them every 2–5 years, depending on how abrasive the water is.

In order to function properly sprinklers should be operated at the pressure indicated in the sprinkler's design specifications. For most wheel-line and hand-line sprinklers this is between 40 psi and 60 psi. At higher pressures, the stream of water is too broken up as it leaves the nozzle, so the application rates just next to the sprinkler riser will be too high (Figure 7).

At very low pressures, the water does not break up enough as it leaves the nozzle. Consequently, the sprinkler applies water in a doughnut pattern that does not apply enough water in between the sprinkler riser and the radius at which most of the water hits the ground (Figure 7).

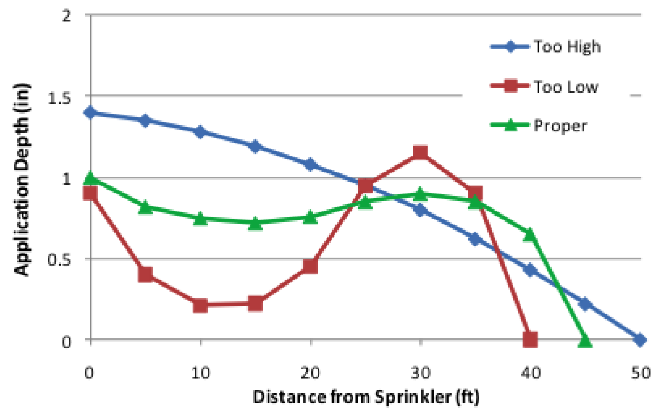

Figure 7. Application depths (patterns) with respect to distance from sprinkler head for pressure settings that are too high, too low, and properly adjusted.

Higher pressures also result in higher nozzle flow rates. On a sloped field, the downhill sprinklers will have more pressure than those at higher elevations. This will result in inadequate water application to the higher field elevations. Pressure-compensating nozzles are available that flow at nearly the same rate regardless of operating pressures. These nozzles are recommended for fields with elevation differences greater than 15–25 ft.

Sprinkler performance is highly dependent on nozzle size and operating pressure. Try to ensure both are correct.

Application Rate or Depth

The best way to determine application rate or depth during an irrigation event is to measure it directly. This is easily done by setting a straight-sided can (e.g., coffee or soup can) under the sprinkler during an irrigation cycle and measuring the depth of the water caught. Remember that sprinklers apply different amounts of water at different points (this is why sprinkler overlap is so important). Using a point approximately 1/3 to 2/3 of the throw distance from the pipeline should provide a good average. Setting additional cans or buckets out at different points (e.g., a square grid-like pattern, 10 ft on each side), will provide a better estimate of the average.

If a direct measurement cannot be taken, an alternate method is to calculate the application rate or depth using the sprinkler's nozzle diameter and pressure, and the sprinkler's spacing. The WSU publication "Sprinkler Irrigation—Application Rates and Depths" (Ley 1992) provides the steps for these calculations. Additionally, live calculators, many of which are optimized for use with smart phones, are available at http://irrigation.wsu.edu (Peters et al. 2011).

References

Beard, F.R., R.W. Hill, and B. Kitchen. 2000. Maintenance of Wheelmove Irrigation Systems. http://www.msuextension.org/ruralliving/Dream/PDF/maintainwheelline.pdf.

Hill, R.W. 2000. Wheelmove Sprinkler Irrigation Operation and Management http://extension.usu.edu/files/publications/publication/ENGR_BIE_WM_08.pdf.

Ley, T.W. 1992. Sprinkler Irrigation – Application Rates and Depths. Washington State University Extension Publication EB1305 http://cru.cahe.wsu.edu/CEPublications/eb1305/eb1305.pdf.

National Center for Appropriate Technology. The Pacific Northwest Irrigator's Pocket Guide. Butte. 2009 http://www.ncat.org/pdf/PNW_Water_Mgt.pdf.

Peters, R.T., H. Neibling, M. English. (Last accessed Mar. 2011). Irrigation in the Pacific Northwest http://irrigation.wsu.edu/mobileirr/Calculators/Sprinkler/Application-Rate.html.

WASHINGTON STATE UNIVERSITY EXTENSION

By **R. Troy Peters**, PE, PhD, WSU Prosser Irrigated Agriculture Research & Extension Center.

FS044E