# IRRIGATION SYSTEMS

Probably the most fundamental best management practice for irrigation is choosing the right system. This requires more than grower experience. Your irrigation system should be designed by experts.

An irrigation system has some form of the following components:

- water source
- power source
- pumps
- conduit pipe
- filtration
- emission points, e.g., sprinklers
- water-efficient hardware.

All components must be suitably matched.

In this chapter, components of irrigation systems will be described and evaluated to help you choose the best system for your operation.

The main principle of irrigation is quite simple: to provide the root zone of your crop with usable amounts of water during periods of need. This is accomplished by delivering irrigation water to a field and then distributing it within the field. In Ontario, three methods are used for the in-field distribution of irrigation water:

- sprinkler irrigation – spraying the water over the entire soil surface of the field
- micro-irrigation (trickle, drip) – piping the water directly and only applying the water to the soil around each plant
- sub-irrigation – piping water into the soil below the root zone.

The techniques of each system are quite different and have inherent advantages and disadvantages.

For all systems, some prefiltration of water is required. The level of filtration will vary depending on system type and design.

## FOOD SAFETY AND DIFFERENT IRRIGATION SYSTEM TYPES

If irrigation water becomes contaminated, it could potentially contaminate the produce. This risk is higher for irrigation systems where the water is sprayed over the plants and comes in contact with the produce, i.e., most types of sprinkler irrigation. You can greatly reduce the risk of contamination by applying water in such a way that it does not directly contact the produce, i.e., micro-irrigation and sub-irrigation. The decision of what type of system to choose will depend on the product being grown. Crops that are not consumed, are used for feed or are processed are considered lower risk. Crops that are consumed raw, especially those that go directly to the table or that may be difficult to clean, are considered high risk.

# IRRIGATION SYSTEMS

**This diesel-powered pump on a pad is drawing water from a pond.**

**A conduit pipe carries water to the field.**

**All systems have emission points – in this case, a big gun irrigation distributor.**

## SPRINKLER IRRIGATION

### Design & Hardware

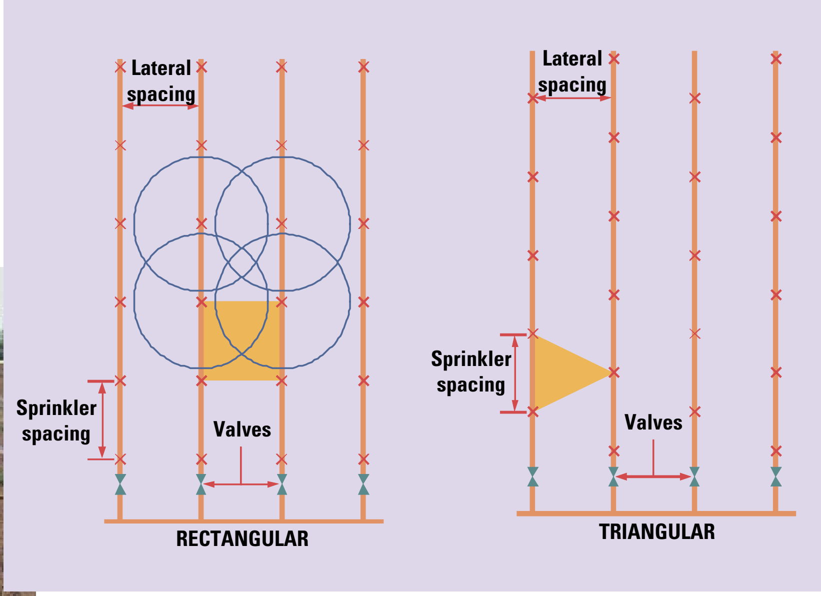
- network of pipes transmits water to all areas of the field to be irrigated
- irrigation pipe transmits water from the pump to the nozzles for application to the desired site
- pipes can be located on or below the ground surface and must be properly sized
- pipe material is aluminum, PVC, polyethylene, steel or concrete, and comes in many sizes
- sprinkler head is the component that evenly distributes the water over the field surface
- special heads are available for only a part-circle application
- in all systems, a proper design is required to match the water supply, the pump, the piping and all sprinklers at the proper spacing, in order to achieve the desired application rate and evenness of distribution

# IRRIGATION SYSTEMS

### How It Works

- water is distributed in a circular pattern
- a 50% overlap of application is usually required to get an even distribution of water
- water is applied in the form of an aerial spray, either above or below the crop canopy
- entire cropland surface receives intermittent applications of water
- has been used on a variety of crops in Ontario for over 50 years

Here is an example of a hand-move portable system.




In sprinkler irrigation systems, sprinklers are laid out in a square or triangle. The water is applied in a circular pattern.

## FIXED SPRINKLER SYSTEMS

## HAND-MOVE PORTABLE SYSTEM

### Design & Hardware

- a network of evenly spaced lateral pipe (aluminum 2–6 inches diameter [50–150 mm]) fed by a movable main trunk line
- sprinklers are evenly spaced along the lateral lines (usually 50% overlap of coverage)
- rate of application is determined by the sprinklers that are used – minimum: 0.1 in/hr; maximum: 2.0 in/hr (2.5–50 mm)
- volume of application depends on how long the system is operated in one position: lower-rate sprinklers for a longer period of time or higher-rate sprinklers for a shorter period of time
- main trunk line must be small enough to move by hand – this can be a limiting factor on how much area can be irrigated at any one time
- pump size and power requirements can be kept low by irrigating in zones

# IRRIGATION SYSTEMS

## How It Works

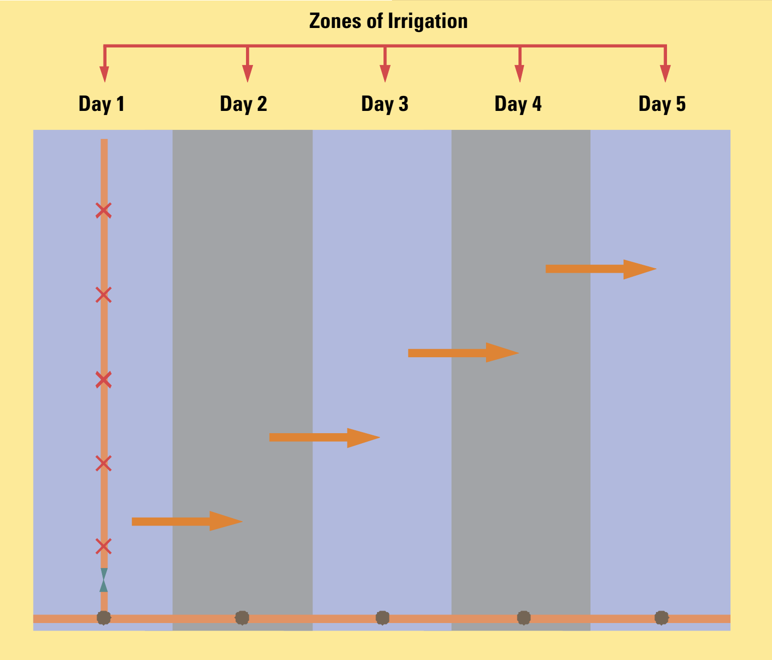
- each irrigation set waters a section of the field
- size of average single system: 1–40 acres (0.5–16 ha)
- after a section of the field is watered with a predetermined amount, the system is moved by hand to the next section to be irrigated
- the system is usually moved every few hours and can be operated 24 hours a day
- after a certain number of days, the entire field is then irrigated and the cycle is started again
- the number of moves is a balance of how many times the system can be moved, the area to be irrigated, over what period of time, and the coverage area of the system
- system is very portable – entire system can be moved from field to field or farm to farm as long as there is a water supply available
- primarily for horticultural crops, especially vegetables

## Capital & Labour

- initial capital cost is usually the lowest of any sprinkler system; labour requirements are the highest
- labour: 0.5–1.5 hr/acre-irrigated (1.25–3.75 hr/ha)

## Advantages (+) & Disadvantages (–)

\+ can be low initial capital cost
\+ flexible use system
\+ can be used for frost protection
– gets in the way of tillage
– very high labour requirement
– washes crop protection materials off leaf and fruit in orchard crops unless low-trajectory system used
– some crop damage usually results from moving lines
– can be a food safety risk, since water contacts produce, and lower-quality irrigation water could potentially contaminate it




Hand-move systems are designed with a network of evenly spaced lateral pipes and main line to irrigate one section of a field at a time.

# IRRIGATION SYSTEMS

## SEMI-PERMANENT SYSTEM (main supply lines buried)

### Design & Hardware

- very similar to the hand-move portable system, except that the water is delivered to the system through a permanent main line that's usually buried
- valves project to the surface and the lateral lines are attached, thus eliminating the need to move the main line, as the laterals are moved to different sections of the field
- water application rates vary, 0.1–2.0 in/hr (2.5–50 mm/hr)
- as larger set areas are irrigated, the pump size and power requirements increase as well

### How It Works

- system allows for larger areas to be irrigated in one set, since the main trunk line is not hand-moved and size isn't a limiting factor
- less portable – only areas serviced by the buried trunk main can be irrigated
- primarily for vegetable and other horticultural crops

**Semi-permanent systems are identical to hand-move portable ones, except that the main lines are buried.**

### Capital & Labour

- the initial capital cost usually increases because of the buried main line – but cost is still moderate if the field is irrigated in sections
- very high capital cost if entire field is irrigated at one time (solid-set is not moved)
- labour requirements are lower than hand-move but still high because the laterals have to be moved after each irrigation – more coverage, larger trunk main, fewer sets, fewer moves, less labour, more capital cost

### Advantages (+) & Disadvantages (–)

\+ the main trunk line is buried and presents less obstruction to travelling or tilling the fields
\+ can provide frost protection
– can be a food safety risk, since water contacts produce, and lower-quality irrigation water could potentially contaminate it

**Hydrants that project to the surface can be used with semi-permanent systems and trickle systems, like the one shown here. Buried main lines don't obstruct traffic as much, and require less labour.**

# IRRIGATION SYSTEMS

## SOLID-SET PERMANENT SYSTEM

### Design & Hardware

- ▶ similar network of pipe and sprinklers to hand-move system
- ▶ pipes may be buried or put on the surface in the spring (buried pipes will obstruct traffic less)
- ▶ sufficient pipe and sprinklers are required to cover entire field
- ▶ pump and power requirements are generally high – pumping requirements may be reduced if the field is irrigated in segments using valves

### How It Works

- ▶ no pipes are moved
- ▶ entire field can be irrigated at the same time or in sequence, allowing for flexibility in the rates and volumes applied, e.g., smaller volumes can be applied more frequently

### Capital & Labour

- ▶ highest initial capital cost
- ▶ not portable
- ▶ labour requirements are low
- ▶ operation needs to be scheduled and the system requires maintenance

### Advantages (+) & Disadvantages (–)

+ entire field can be irrigated at the same time or in sequence – beneficial for frost protection, evaporative cooling and chemigation
+ do not have to move any pipe – less labour
+ water efficiency – when properly scheduled, smaller volumes can be applied as needed
– highest initial capital cost
– can be a food safety risk, since water contacts produce, and lower-quality irrigation water could potentially contaminate it

**Initial capital costs for solid-set systems are very high, but labour requirements are very low.**

# IRRIGATION SYSTEMS

## FIXED-VOLUME GUN HAND-MOVE SYSTEM

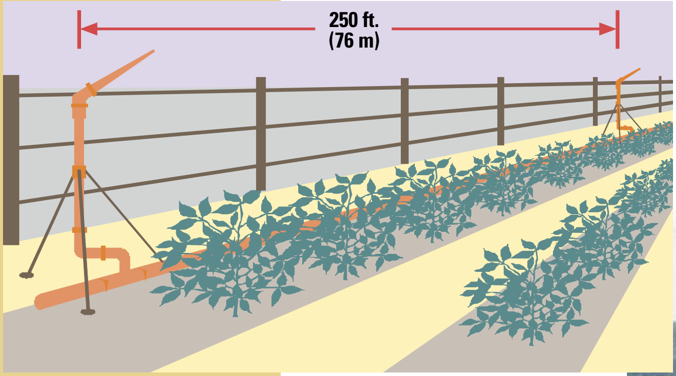
### Design & Hardware

- water is supplied by aluminum and rigid or flexible plastic pipe
- makes use of high-volume sprinklers (guns) capable of discharging 50–1000 gpm under operating pressures of 40–130 psi
- nozzles range from 0.5–2.0 inches (12–50 mm) in diameter; water can be projected up to 250 feet (75 m)
- application rates are high: minimum: 0.25 in/hr; maximum: 2.0 in/hr (6–50 mm/hr)
- pump size and power requirements are generally high

### How It Works

- water is projected quite high, and distribution evenness can be greatly affected by wind
- one setting can irrigate up to 4.5 acres (2 ha)
- size of average single system: 20–40 acres (8–16 ha)
- guns are moved by hand from setting to setting, or they are mounted on trailers and moved with a tractor
- system is similar to conventional sprinkler except there are fewer sprinkler positions and line positions
- system is very portable and can be moved from field to field wherever there is water supply
- normally used in potatoes, tobacco and nursery stock

**Large-diameter, crushable (lay-flat) hose can be used on laneways and access roads. The hose can be driven over without damaging the system.**




**High-volume guns fixed to aluminum pipe can project water up to 250 feet (76 m).**

**Stationary guns mounted on wheeled frames are also used in the fixed-volume gun hand-move system. Such systems require supervision to avoid runoff on sloping land.**

# IRRIGATION SYSTEMS

**Capital & Labour**

- initial capital cost is moderate
- labour requirements are moderate (0.5–1.0 hr/ac/irrigation, sometimes > 1 hr/ac/irrigation [1.25–2.5 hr/ha/irrigation]) – but management requirements are moderate to high, as there's a steady requirement for attention and frequent resetting of guns due to high application rates

**Advantages (+) & Disadvantages (–)**

\+ easy to use, easy to maintain
– easy to mismanage – system has some labour requirements
– can lead to runoff and erosion on sloped land
– can cause compaction (surface crusting)
– guns are more subject to wind disrupting the coverage pattern
– not recommended for frost protection
– can be a food safety risk, since water contacts produce, and lower-quality irrigation water could potentially contaminate it

## MOBILE SPRINKLER SYSTEMS

### TRAVELLING GUN SYSTEM

**Design & Hardware**

- uses the high-volume gun sprinkler technology mounted on a trailer or a sled
- water supplied by a flexible plastic hose attached directly to pump, or flexible plastic hose connected to an aluminum main supply line
- only part-circle gun sprinklers are used for two reasons: better uniformity of water application, and so that the trailer or sled doesn't have to be pulled through wetted soil
- application rates are high: minimum: 0.25 in/hr; maximum: 2.0 in/hr (6–50 mm/hr)
- volume of water applied per acre can be adjusted by the travel speed of the sled or trailer, giving some flexibility
- pump size and power requirements are generally high
- booster pump may be required at gun to maintain adequate operating pressure

**A reel device pulls a mounted gun down the field – irrigating as it goes.**

# IRRIGATION SYSTEM

**SAFETY**

**Low-pressure systems (< 50 psi) are inherently safer and also consume less energy. The risk of injury is greater with high-pressure systems (> 80 psi) because of blown lines, line jumping, guns flipping, etc.**

### How It Works

- one unit can irrigate approximately 1 ac/hr with 1 inch of water (41,603 L/ha/hr) – many nozzle sizes are available
- size of average single system: 3–140 acres (1–57 ha)
- moved to each location by tractor
- trailer or sled is pulled down the field by a winching device (cable) or reel device (plastic pipe), irrigating the field as it moves
- after each pass of the field, the unit is moved to the next position
- very portable
- suitable for irrigating high- and low-growing crops – commonly used on tobacco, sod, potatoes, tomatoes, tree fruits and grapes
- best suited to flatter ground

### Capital & Labour

- initial capital cost is moderately high
- labour requirements are low: 0.1–0.3 hr/ac/irrigation (.25–.75 hr/ha/irrigation)
- entails steady supervision – emergency "kill" switches on the pumping unit are a must

### Advantages (+) & Disadvantages (–)

+ easy to use and maintain under ideal management
– easy to mismanage as mechanics are more complex
– can lead to runoff or erosion on sloped land
– can cause compaction
– subject to wind disruption of coverage pattern
– not generally used for frost protection
– limited distance due to capability of travelling reels
– can be a food safety risk, since water contacts produce, and lower-quality irrigation water could potentially contaminate it

# IRRIGATION SYSTEMS

## LOW-PRESSURE BOOM TRAVELLER SYSTEM

### Design & Hardware

- ▸ similar to the travelling gun system except the gun is replaced by a boom
- ▸ also similar in design to a field sprayer equipped with sprayer nozzles
- ▸ booms range in width, 40–235 feet (16–72 m)

### How It Works

- ▸ application volume is varied by the speed of the reel
- ▸ works under low horsepower (10–50 hp)
- ▸ application rates are high
- ▸ one unit can irrigate approximately 0.2 ac/hr – 0.9 ac/hr with 1 inch of water

**The low-pressure boom traveller system is similar to a travelling gun, except that the gun is replaced by a boom with low-pressure nozzles.**

### Capital & Labour

- ▸ moderate capital cost – considerable drop in capital cost per acre if used on large acreages
- ▸ labour requirements are low
- ▸ supervision is necessary to prevent runoff

### Advantages (+) & Disadvantages (–)

+ can be used on delicate crops (e.g., spinach) because it delivers fine droplets
+ not significantly affected by wind because delivery is close to the ground
+ by using drag hose or sock attachments, water is less likely to come into contact with the produce, thus reducing food safety risks associated with irrigating with lower quality water
– works best on soils with high infiltration rates (sandy soils)
– requires supervision or runoff will occur
– limited strip width of 40–235 feet (16–72 m)
– limited distance due to capacity of travelling reels
– not useful for frost protection
– food safety risks – unless a drag hose or sock is used, water contacts produce, and lower-quality irrigation water could potentially contaminate the produce

**Low-pressure spray nozzles apply fine droplets, making this system useful for delicate crops.**

# IRRIGATION SYSTEM

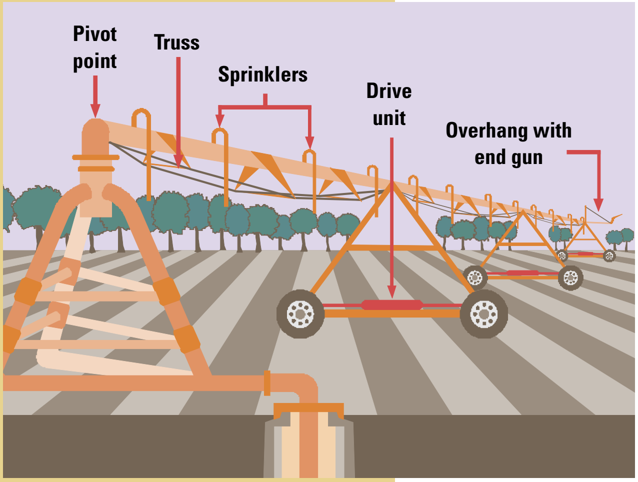
## CENTRE PIVOT SYSTEM

### Design & Hardware

- system consists of a single lateral, supported by trusses and towers on wheels, with one end anchored to a fixed pivot centre
  - lateral can extend 375–2000 feet (15–600 m)
- other end is free to move in a circle about the pivot
- can use normal mid- to low-pressure impact, high-pressure gun, drop tubes and/or low-pressure spray sprinklers either on top of or below the lateral
- water application rates: minimum: 0.2 in/hr; maximum: 10 in/hr (5–250 mm/hr)
- tower supports are 120–200 feet (35–60 m) apart and are driven by electric, hydraulic (water or oil), or air-pressure energy
  - speed of rotation is usually electronically controlled
- pump size and power requirements are usually high due to large application area
- low-pressure nozzles reduce the requirement for power and pump size

### How It Works

- water is fed into the lateral through the centre pivot and distributed from the lateral by sprinklers (high- or mid-pressure), or low-pressure spray nozzles
- a 1600-ft. (490-m) lateral can irrigate an area of 195 acres (80 ha) in one setting
- size of average single system: 7–500 acres (3–200 ha)
- application rate increases toward the outer end of lateral because more area must be covered, and is determined by the sprinkler selection
- in order to get uniform application volumes, sprinklers along lateral are either:
  - evenly spaced along lateral, but are sized to give a higher volume output from each successive sprinkler as the distance from the sprinkler increases, or
  - the same size but spaced closer together as the distance from pivot increases
- gun can be placed at the end to irrigate the corners
- low-pressure drop nozzles are more water-efficient than high-projectile sprinklers/guns
- total irrigation application dependent on the speed of travel, which is variable – one rotation usually completed within 24 hours
- suitable for potatoes, onions and other vegetables




**A centre pivot system consists of a single lateral supported by wheeled towers and trusses. It moves about in a circle from a fixed pivot and is fed pumped water.**

# IRRIGATION SYSTEM

**Capital & Labour**

► initial capital cost is high

► very low labour requirements: 0.05–0.15 hr/ac/irrigation (0.13–0.38 hr/ha/irrigation)

**Advantages (+) & Disadvantages (–)**

+ can function effectively on rolling ground
+ easy to use and maintain once system is understood
+ very low labour requirements (high level of automatic control)
+ good range of application rates available
+ system type suited for both larger and smaller areas
+ a low-pressure nozzle increases water use efficiency; sprinklers/guns are less efficient
+ can be automated
+ can be equipped to shut off from remote location
– high capital cost
– can be moved, but better suited to one location
– large flow rates are used
– large reservoirs of water needed
– crop rotation must be carefully planned
– very high power requirements are often needed
– cannot protect from frost
– will not irrigate corners of field unless special devices are attached to end of lateral line that engage in the corners of the field only
– system is portable and can be towed from farm to farm – but it's not an easy move unless it's in the same field (2–4 hours)
– can be a food safety risk, since water contacts produce, and lower-quality irrigation water could potentially contaminate it

This is an older centre pivot, which consumes more energy because of its high-pressure sprinklers.

Irrigation systems with low-pressure drop tubes offer greater water efficiency.

# IRRIGATION SYSTEMS

## LATERAL MOVE SYSTEM

The lateral move system is mechanically similar to the centre pivot, except that it moves sideways across a field in line, irrigating a rectangular section.

### Design & Hardware

- very similar mechanical construction to the centre pivot, except that entire elevated lateral moves across the field in line, and irrigates a rectangular section
- water is delivered to the system by a flexible hose or by use of an open ditch
- all types of sprinklers can be used in the design
- typical water application rates: minimum: 0.2 in/hr; maximum: 2 in/hr (5–50 mm/hr)
- application rate is the same from one end of the system to the other
- speed of each drive unit electronically controlled to keep in line
- lateral can extend up to 2,600 feet (800 m)
- pump size and power requirements are high because of large area usually irrigated (low compared to travelling gun system)

### How It Works

- total application is controlled by travel speed of lateral (variable control)
- best suited for irrigation of large acreage: size of average single system is 80–500 acres (32–200 ha)
- system is somewhat portable on the smaller units between adjacent farms, but it isn't an easy move
- suitable for potatoes and strawberries (where frost protection is not required)

Lateral move systems have a high initial capital cost, but don't require much labour.

### Capital & Labour

- initial capital costs are high
- very low labour requirements: 0.05–0.15 hr/ac/irrigation (0.13–0.38 hr/ha)

### Advantages (+) & Disadvantages (–)

\+ very low labour
\+ good range of application rates available
\+ by using drag hose or sock attachments, water is less likely to come into contact with the produce, thus reducing food safety risks associated with irrigating with lower quality water
\+ easy to use once system is understood (high-tech electronic controls)
– high capital cost
– generally for one field location
– cannot provide frost protection

# IRRIGATION SYSTEMS

## MICRO-IRRIGATION *(also called drip or trickle)*

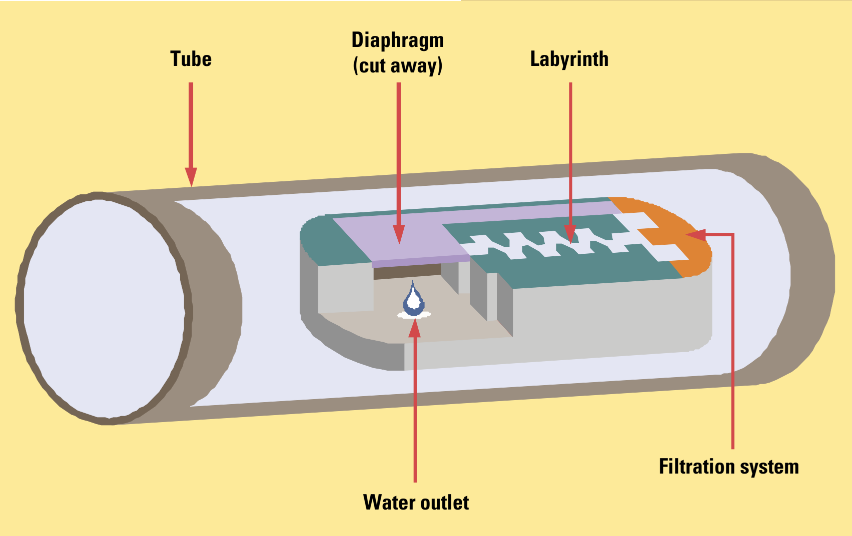
**This is a drip emitter, which provides a point source for water discharge.**

**This spray emitter has no moving parts and can be inserted into the line.**

**Shown above is a tape system, where emitters are usually built into the seam of the hose.**

### Design & Hardware

- a network of evenly spaced lateral lines (polyethylene ³⁄₈ – 1.5 inch diameter [10 mm–38 mm]) fed by sub-mains and main trunk lines
- emitters (the equivalent of sprinklers in other systems) may be evenly spaced along the lines to irrigate a continuous row (8–24 inches apart [200–600 mm]) or grouped near each plant (e.g., for orchards)
- emitters may be in line or offset
- systems require filtration units to provide clean water and avoid emitter plugging
- systems generally require pressure regulators at the head of the sub-mains
- pumps are smaller, less power is required, less energy is used, and the water conveyance lines are smaller
- a high level of design is imperative for this system to operate properly, especially on rolling terrain – pressure-compensating emitters can largely overcome the challenge presented by uneven terrain and long runs: the emitter will deliver more volume by opening up when pressure is reduced and less volume by closing down as pressure is increased, resulting in a uniform flow rate




**In-line emitters like this can be designed with pressure-compensating features that help maintain the same discharge rates throughout an irrigated field. Pressure-compensating emitters deliver the same flow rate over a wide range of line pressure. This overcomes the problem of slope and distance from the pump.**

# IRRIGATION SYSTEMS

## Systems

- there are three main categories:
  - **tape**: thin-walled hose with the discharge system built into the seam of the hose or manufactured inside the hose (wall thickness 0.004– 0.020 inches [.10–.50 mm])
  - **drip emitter**: thicker hose with emitters plugged in or manufactured inside the hose to provide a point source for water discharge
  - **spray emitter**: thick hose with emitters plugged in that distribute water by means of a spray pattern (diameter of throw is less than 10 feet [3 m])
- microsprinklers are not considered in the same category as the above micro-irrigation techniques
  - provide water to the entire soil area instead of just the plant root zone
  - can be distinguished by having a moving part such as a spinner or other device to increase the diameter of throw
  - higher flow rates >25 US gph (>100 Lph )
- older systems supplied water almost on a 24-hour basis during times of need (low pressure/very low flows); newer systems use higher flow rates, and can apply the desired amount of water in 4–8 hours on a daily basis
- higher flow rates reduce emitter clogging problems (larger orifices) and field can be irrigated in sections or zones, thereby reducing the pump sizes
- a 3 hp electric pump is capable of supplying the power to irrigate an extensive orchard planting – by breaking the planting into zones holding approximately 1,000 trees/zone, the pump feeds approximately 2.5 acres (1 ha) of planting at a time
- clean water is a must for emitters to function properly, and to reduce maintenance requirements – filtration systems are needed

**Drip irrigation provides a small wetting pattern above the rooting zone. Below soil level, the wetting zone fans out.**

## Filters

- there are three main types:
  - **screen**
  - **disk**
  - **sand**
- choice of filter type should be based on water quality and emitter orifice size
- filters must be back-flushed to keep them clean and operating properly – this backflushing may be automated or done manually
- filters are classed by the size of the openings of their mesh, which is called "mesh equivalent"
  - e.g., 100 mesh equivalent = 0.1520 mm; 200 mesh equivalent = 0.0740 mm
  - a minimum of 80 mesh screen must be used for any trickle irrigation system

Note: disk filtration systems are often mounted on a mini-trailer for easy portability

# IRRIGATION SYSTEMS

## FILTER TYPES

| FILTRATION TYPE | PORTABILITY (able to move it between sites) | ABILITY TO DEAL WITH HIGH LEVELS OF ORGANIC PARTICLES | ABILITY TO HAVE AUTOMATED BACKFLUSH |
|---|---|---|---|
| SCREEN FILTER | Yes | Low | Yes |
| DISK FILTER | Yes | High | Yes |
| SAND FILTER | No | High | Yes |

Screen filter

Sand filter

Disk filter

### How It Works

- ▸ system supplies a small amount of water ($\frac{1}{2}$–2 US gal/hr [2–8 L/hr]) near the base of each plant – the amount of water is controlled by the length of time the system runs
- ▸ system components can be downsized because water is delivered on a more continuous basis (usually on a daily basis when needed) and only the rooting areas are watered (not between the rows)
- ▸ used most commonly for fruit trees, berry crops, vegetable and ornamentals

### Capital & Labour

- ▸ very low labour requirements once the system is in place
- ▸ labour is required to ensure that emitters are not plugged and equipment operates properly

# IRRIGATION SYSTEMS

**Advantages (+) & Disadvantages (–)**

+ based on the concept of preventing rather than relieving moisture stress – crop response is good
+ very low labour
+ easily automated
+ water-efficient: can reduce water usage by one-third to one-half compared to overhead systems
+ can be used for fertigation
+ can be applied on windy days or during spraying operations
+ can be functioning without interruption of harvest operation
+ foliage is not wetted – reduces disease problems for some crops and does not remove crop protection materials from leaf canopy or maturing fruit
+ operating costs are relatively low
+ weed problems are reduced since only crop rows are irrigated
+ water does not come into contact with the produce and therefore the food safety risk associated with lower quality water is reduced
– water supplies must be dependable
– cannot be used for frost protection
– crop could suffer badly if irrigation is interrupted during a dry period
– occasional rodent damage
– may present a problem where tillage or mowing devices are used near crop row – line can get tangled in equipment

## SUBSURFACE DRIP IRRIGATION

**Design & Hardware**

► the same as regular drip irrigation, except that in this case lateral lines are buried (see details on page 61)
► burial depth for lines will depend on crop rooting depth and soil type
► it's important to install lateral lines with emitter orifice pointing up

**Drip tape can go above and below ground. Here you can see the wetting pattern from a subsurface drip irrigation tape.**

# IRRIGATION SYSTEMS

**How It Works**

- ▸ system supplies water directly to the plant roots, beneath the soil surface
- ▸ system supplies a small amount of water on a frequent basis (usually daily)
- ▸ **root intrusion**
  - ▹ irrigation applications must be frequent to avoid root intrusion
  - ▹ deficit irrigation is not appropriate for subsurface drip irrigation systems, since it may lead to roots intruding into emitters
  - ▹ in woody plantations, irrigation must continue throughout growing season even after harvest, as roots are still growing, and if irrigation is stopped, the roots may aggressively seek water and move into the emitters
  - ▹ to prevent root intrusion, use acid flushing or emitters designed to prevent the entry of roots
  - ▹ once root intrusion occurs, the system must be replaced

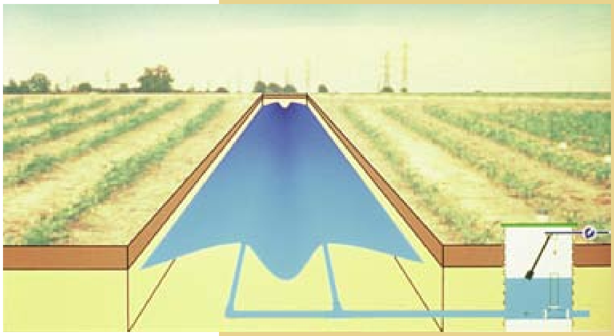
**Advantages (+) & Disadvantages (–)**

+ less water evaporation from soil surface
+ no interference with crop operations even during irrigation event
+ wets a larger soil volume, reducing deep percolation
+ reduces animal damage to laterals
– potential for root intrusion
– potential for lateral lines to become pinched, restricting water flow
– difficult to monitor system since it is buried and not visible
– must rely on pressure gauges and flow meters to make sure the system is working as designed
– do not install in areas where compaction or high traffic will collapse the lines

## CONTROLLED DRAINAGE / SUB-IRRIGATION

A subsurface irrigation system uses the existing tile drainage network to maintain, raise or lower the water table height. The concept is to keep the water table near the bottom of the root zone.

By capillary action, water is made available in the area of the roots. Two systems may be used to assist in the management of the water table: controlled drainage and sub-irrigation.



**With controlled drainage (no water added) or sub-irrigation (water added), the water table level is controlled so that water can be drawn up the root zone by capillary action.**

# IRRIGATION SYSTEMS

## CONTROLLED DRAINAGE

### Design & Hardware

- flow-level control devices are installed at the outlets of the tile or at strategic points of the subsurface drainage system (e.g., rubber flap valve)
  - flow control devices are kept open to allow drainage during spring melt and frequently during planting
  - flow control devices will be kept open for drainage (i.e., in spring) and are closed for the rest of the growing season, unless it rains enough to require drainage
- tiles are typically 30–36 inches (750–900 mm) below the ground surface, and will draw the water table down to that depth
- when flow control devices are activated, the water table will only be lowered to a depth of 16–18 inches (400–450 mm) just below the primary root zone
- site requirements:
  - field must be systematically tile drained
  - best suited to fields that are relatively flat
  - higher sloping fields can be done, but additional cost and management are required
  - must have an impervious layer at or near the depth of the tile system; otherwise, the water table drops too quickly for any benefit to be realized – may require a careful study of the soil horizons

### How It Works

- not a true irrigation system
- delays the need for irrigation by making better use of the water before it drains from the soil
- manages the function of a subsurface drainage system
  - subsurface drainage system is designed to remove gravitational water from the soil, so that the water table is lowered to a depth for optimum growing conditions
  - even after attaining the desired water table depth, excess water is removed until the water table is lowered to the depth of the drainage system
- by using controlled drainage techniques, some of this water normally removed by conventional drainage could be used as a source to replenish the root-zone moisture content (through capillary action)
- the system simply controls how far the water table is drawn down by the drainage system
- water isn't added: it extends the time period before irrigation or rain is required

# IRRIGATION SYSTEMS

## SUB-IRRIGATION

### Design & Hardware

- ► site requirements
  - ▷ imperative that an impervious layer of soil be at or below the tile depth in order to retard the downward movement of the water
  - ▷ if this layer doesn't exist, the water table level cannot be maintained and benefits will not be gained
  - ▷ soils with a naturally high water table are also suitable; naturally well-drained soils are not suitable
  - ▷ flat or low-sloped fields are best for this system
  - ▷ test holes need to be dug throughout the field to identify the soil profile and the impervious layer

### How It Works

- ► functions the same as controlled drainage system, except that water is added to the system to maintain the water just below the primary root zone
- ► tile system provides the path for water to drain in the spring and for water to be reintroduced to the soil to maintain the water table during the growing season
- ► depending on the water source, water is pumped into the tile system or provided by gravity
- ► water can be put into the tile at the high or low end

### Advantages (+) & Disadvantages (–)

+ low maintenance and low labour
+ doesn't impede the tillage and surface operations of the field
+ research has shown additional benefits from sub-irrigation systems besides yield increases: more efficient use of nitrogen (less loss to ground or surface water), and reduction in deep percolation of pesticides
+ water doesn't contact the produce, thereby reducing food safety risks associated with irrigating with lower quality water

– on sloping fields, it may be necessary to divide the field into sections
– in retrofit situations, a good knowledge of the existing drainage system is required (location, slopes, depths etc.)
– not suitable for frost protection
– must have adequate water supply

**This commercially available sub-irrigation unit will help control the amount of irrigation water supplied to the drainage system.**

# IRRIGATION SYSTEMS

## IRRIGATION PRICES: $ PER ACRE

| IRRIGATION SYSTEM | 15 ACRES | 50 ACRES | 100 ACRES |
|---|---|---|---|
| HAND-MOVE PORTABLE | 1540<br>3 moves<br>5 ac. irrigated/move | 980<br>5 moves<br>10 ac. irrigated/move | N/A |
| SEMI-PERMANENT | 1575 | 865 | N/A |
| SOLID-SET | 3580 | 3250 | 3070 |
| FIXED-VOLUME GUN, HAND-MOVE | 2100 | 1440<br>48 moves of gun | 900<br>84 moves of gun |
| TRAVELLING GUN | 1985 | 900 | 700 |
| TRAVELLER WITH BOOM | 3000<br>7 moves | 1715<br>5 moves | 915<br>9 moves |
| CENTRE PIVOT | N/A | 890<br>incl. generator | 750<br>incl. generator |
| MICRO PIVOT | 1575<br>no generator incl. | 860<br>mobile pivot, 2 circles | N/A |
| LATERAL MOVE | N/A | 1240<br>micro lateral | 990<br>large lateral |
| All pivots and laterals are subjected to the size and shape of field. Power is required to drive pivots or laterals. Generators may or may not be included in price: see above. | | | |
| **DRIP/MICRO IRRIGATION** | **15 ACRES** | **50 ACRES** | **100 ACRES** |
| DISPOSABLE TAPE/THIN WALL | 1078<br>(230/ac/yr to replace tape) | 822/ac<br>(219/ac/yr to replace tape) | 750/ac<br>(219/ac/yr to replace tape) |
| HEAVY WALL/PERMANENT DRIP TUBING<br>(15-year life on drip tube) | 3040 | 2550 | 2325 |

**Assumptions: All pricing based on close water supply and minimal suction lift. Fields are relatively flat and shaped such that main supply lines are minimal.**

**Power supply not included.**

**To convert to costs per hectare, multiply cost by 2.48.**

# IRRIGATION SYSTEMS

## IRRIGATION PUMPS

A major component of any irrigation system is the pump. Water must be delivered to all sprinklers or emitters at the proper pressure and flow rate. The pump and motor must be adequately matched to perform the desired function. A proper match will ensure an economical system that can save you dollars on maintenance and operation.

Each irrigation pump has unique flow characteristics that vary with pump rpm and operating pressure. The pump must be matched to the total irrigation flow rate and the total dynamic head:

- total irrigation flow rate at any one time – determined by flow rate from the maximum number of sprinklers or emitters that operate at the same time
- total dynamic head developed by the system
  - $H = h_p + h_f + h_s + h_e$
    ($h_p$ = pressure head; $h_f$ = friction head; $h_s$ = static suction head; $h_e$ = static discharge head).

The brake horsepower required by an irrigation pump can be calculated from:

- H.P. = $(Q \times H) / (3960 \times E)$
  - H.P. = Brake horsepower required by system; Q = Design flow rate of system (US gpm); H = Total dynamic head (ft); E = Pump efficiency (% in decimal form).

Pump efficiency can be obtained from a Pump Performance Curve. This curve indicates how the pump performs at different pumping rates, rpm speed, and different resistant forces (H). The higher the efficiency, the more energy that is transferred to the water for movement.

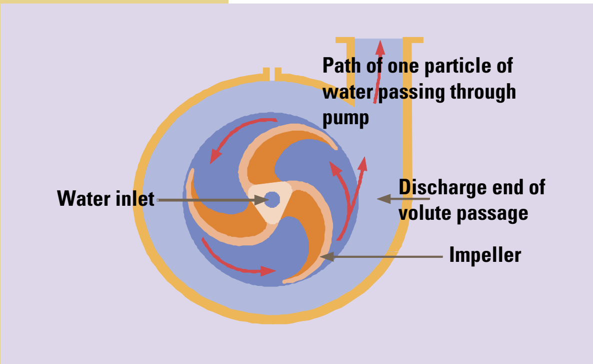
Obtain expert advice when selecting a pump.

## CENTRIFUGAL PUMPS

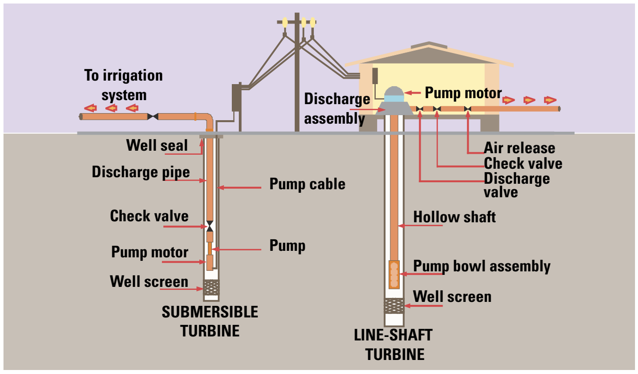
- most common type of pump
- water generally enters the side of the impeller and is spun out by centrifugal force to the outside of the impeller
- should be selected and operated at or close to its **best efficiency point** (BEP), as fuel efficiency will drop
- try to select pumps that have a BEP of 65% or better
- shouldn't be operated at less than 80% of its BEP
- should be located as close to water elevation as possible to minimize vertical suction lift
- water is easier to push up rather than raise by suction

# IRRIGATION SYSTEMS

- used with surface water sources, e.g., ponds, streams
- when used with water sources free of silt or sand, this pump gives many years of dependable service
- can be used with many types of power and power transfer systems, i.e., electric, gas, diesel, power takeoff, etc.
- can be used over a wide range of speeds; suitable for low volumes at high pressure (frost control) or higher volumes at lower pressure (irrigation)




**In a centrifugal pump, the water enters the side of the impeller and is spun out to the outside of the impeller.**




**The submersible pump is most often used in smaller diameter wells with static water levels. The line-shaft turbine pump is better suited to wells with fluctuating head situations.**

## TURBINE PUMPS

### SUBMERSIBLE TURBINE

- usually used when pumping from wells with a static water level below 15 feet (4.5 m)
- most often used in smaller diameter wells
- pump and motor located below static water level in well
- water must be clean of silt and sand
- electrically powered
- mainly used for small volumes

### LINE-SHAFT TURBINE PUMPS

- used in water wells or wells connected to another supply such as a river
- capable of pumping high volumes of water
- often used for high total dynamic head (H) situations or fluctuating head situations
- power supply is at the top of well, and different types can be used, e.g., electrical, internal combustion engines
- pump is located in the well below the static water level
- can operate with less clean water (water that is not crystal-clear)
- higher priced

# IRRIGATION SYSTEMS

## POWER SOURCES

### ELECTRIC MOTORS

**Advantages (+) & Disadvantages (–)**

+ very efficient (85–90%)
+ very dependable and low maintenance
+ if power is readily available, they require less initial cost than internal combustion engines
+ if 3-phase power is available, there are additional savings on motor cost, especially on larger-size motors; however, demand charges apply monthly
+ have a long life expectancy (20–30 years)
+ wide range of sizes available and easy to match the need
+ quiet and clean
+ easy to automate
+ very useful for micro-irrigation (trickle)
– not a very portable power source – power sources are usually fixed locations
– they run at a fixed speed, which doesn't allow for changing pumping rate if that is required (unless equipped with a variable speed drive)
– if power isn't readily available, the initial cost may exceed that of internal combustion engines
– higher capital cost

**Additional Information**

If the power requirements exceed 10 hp, special soft-start motors are required to operate on a single-phase service. These are more costly than conventional motors.

Another option is a 3-phase motor, if that type of power supply is available. Three-phase motors can be used with a single-phase service, but a phase converter must be added ahead of the motor, increasing the cost of the installation.

If you're considering larger systems, you should contact the local hydro utility to ensure that the access lines have an adequate electrical power supply. Line surge charges may be encountered, adding to operating costs if large motors are required. Consult with a knowledgeable electrician for more options.

**This 3 hp electrical pump is used to supply water to a trickle irrigation system.**

# IRRIGATION SYSTEMS

## INTERNAL COMBUSTION ENGINES

**Advantages (+) & Disadvantages (–)**

+ very portable
+ speed can be adjusted to alter the pumping rate for different requirements, e.g., very high speed for big guns
+ large power requirements can be provided more easily
+ can make dual use of existing power supplies, e.g., tractor
– higher maintenance required, e.g., oil changes, tuneups
– less motor size availability
– shorter life
– higher initial cost
– if a tractor is used to drive pump, tractor isn't available for other farming functions
– if tractor is used to drive pump, the motor life is being decreased but other tractor functions are not being affected – in high use situations, a dedicated motor should be used
– Murphy safety switches are essential to eliminate chance of motor meltdown
– noisy and emit fumes
– need to be refuelled

**Additional Information**

There are safety features that should be installed to protect internal combustion engines:

► low irrigation-pressure shutoff
► low oil-pressure shutoff
► high-temperature engine-water shutoff.

**Tractor PTO pumps make good use of existing power sources.**


**Fixed pumps are very portable and can be adjusted to alter pumping rate for different requirements.**

# IRRIGATION SYSTEMS

Direct drive (dedicated use) or PTO systems may be used, as can diesel or gasoline engines. Diesel engines are longer lasting, and have a higher capital cost and lower energy cost than gasoline engines. There has been some interest in the use of natural gas as a fuel source because it costs much less than gasoline. Engines running on natural gas can have a long life expectancy and have a good record for engine starts in cold conditions.

## POWER REQUIREMENTS

| | | |
|---|---|---|
| Water Horsepower (WHP) | = | The actual energy delivered to the water by the pump (hp) |
| WHP | = | Q x H/3960 |
| Where Q | = | Design flow rate of system (US gpm) |
| Where H | = | Total dynamic head (ft) |

## WATER HORSEPOWER PER UNIT OF FUEL

| FUEL | WATER HORSEPOWER HOURS PER UNIT OF FUEL |
|---|---|
| GASOLINE | 2.14 per litre |
| DIESEL | 2.9 per litre |
| ELECTRICITY | 0.885 per kilowatt-hour |

## FUEL COST COMPARISON

| FUEL | TO PRODUCE 10 WHP HOURS | COST PER UNIT OF FUEL ($) | TOTAL COST ($) |
|---|---|---|---|
| GASOLINE | 4.67 litres | 90 | 4.20 |
| DIESEL | 3.44 litres | 80 | 2.75 |
| ELECTRICITY | 11.29 kw-hrs | 0.11 | 1.24 |

**Note: This chart only deals with the fuel costs. It uses average efficiency rates of the motors for each fuel. It does not take into account the costs of installation, the purchase price, maintenance, or the life expectancy.**

# IRRIGATION SYSTEMS

## HARDWARE

Selecting the right hardware is part of choosing and designing an effective irrigation system. Irrigation hardware includes pipes, pipe connections, sprinklers and nozzles. The types of irrigation hardware are presented in the following section to help you choose those most suitable to your irrigation system and crop operation.

## PIPE

### ALUMINUM

- size range: 2–8-inch diameter (50–200 mm); 30-ft length (9.1 m) most common
- approximate weights: 3-inch diameter, 30–40 lb/30-ft section (75 mm, 13.6–18.1 kg/ 9.1 m); 8-inch diameter, 100 lbs/30-ft section (200 mm, 45.4 kg/9.1 m)
- life expectancy is very good (50 years+)
- used for above ground applications only (not suitable for underground use due to corrosion)
- fertigation can reduce the life of the pipe

### PLASTIC

- size range: .5–10-inch diameter (12.7–254 mm) most common; larger sizes are available; 20-ft length (6.1 m) most common
- weighs more than aluminum of equivalent diameter
- mainly used for underground applications (main line distribution system)
- excellent resistance to chemical deterioration
- new products developing for plastic pipe aboveground uses; currently only 3-inch (75 mm) available
- life expectancy is 25–30 years
  - durabilty is unknown, especially in cold weather
  - plastic becomes more brittle with cold temperatures and exposure to sunlight
- suitable for fertigation

# IRRIGATION SYSTEMS

## PIPE CONNECTIONS

Several types are available. The two main types are: knob and latch, and ball and socket.

### KNOB AND LATCH

- when pump is shut off, water can drain from line due to design of gasket
- when pipes are disconnected, water can drain out for moving purposes – this makes moving pipes less difficult

### BALL AND SOCKET

- able to go around some bends and still maintain seal
- when pump shuts off, line remains pressurized
- when sections are disconnected, pipes remain full of water and therefore pipe is heavy to move
- newer types avoid this problem by a method of breaking the seal to let water escape

**One of the advantages of a knob and latch connection is that water can drain from disconnected pipes easily – making moves less difficult.**

**Leaky connections waste water. Monitor and repair your pipe connections.**

# IRRIGATION SYSTEMS

Big-volume guns are very versatile and will move large volumes of water quickly to a crop in need. Low labour requirements make this system very attractive to potential users.

Low-pressure nozzles are used extensively on travelling booms.

A travelling boom with drag hoses and socks applies water directly to soil surface. In this case, water does not contact surface of the product, thereby minimizing plant disease, food safety risks, and evaporation.

## SPRINKLERS

## MATERIAL

### PLASTIC

- approximately 30% less cost than conventional brass sprinklers
- not feasible to repair: wear out, throw away
- are being used in specialty applications, e.g., ginseng (low-trajectory sprinkler under shade canopy)

### BRASS

- guns
- majority of sprinklers are brass
- can be repaired – nozzles can be replaced as they wear
- very durable and long life expectancy
- they can be one- or two-directional
  - one-directional is good for frost protection: reduces water volume
  - two-directional is good for uniformity of application, short and long distance

### LOW-PRESSURE NOZZLES

- based on the principle of water projection onto a cone deflector, creating the spray pattern
- the deflector may be fixed or rotated by the water to create an even, circular pattern
- used extensively on travelling boom, centre pivot or lateral move system
- droplet size created is much smaller than traditional sprinklers
- spray projection distance is much shorter than for traditional sprinklers
- require lower pressure to operate than traditional sprinklers
- can result in significant water savings if used in conjunction with drop tubes that bring the water application closer to the soil surface, thereby decreasing the evaporation losses
- the nozzle size determines the flow at different pressures
- the deflectors determine the spray pattern
- spray pattern options include wobblers, nutators, low drift nozzles, spray heads, quad sprays, rotators, spinners, accelerators, bubblers, fertigators, aerators etc.
- made of plastic, some may have brass or rubber parts

### DRAG HOSE / DRAG SOCK

- can be used for Low Energy Precision Application (LEPA)
- hoses replace sprinklers on travelling boom and lateral move
- water is delivered directly to the ground surface between each or alternate rows
- hose is dragged along the soil surface applying water between the crop rows, and the flow rate is controlled by a nozzle
- plastic sock may be used at the end of the hose to disperse water on soil surface