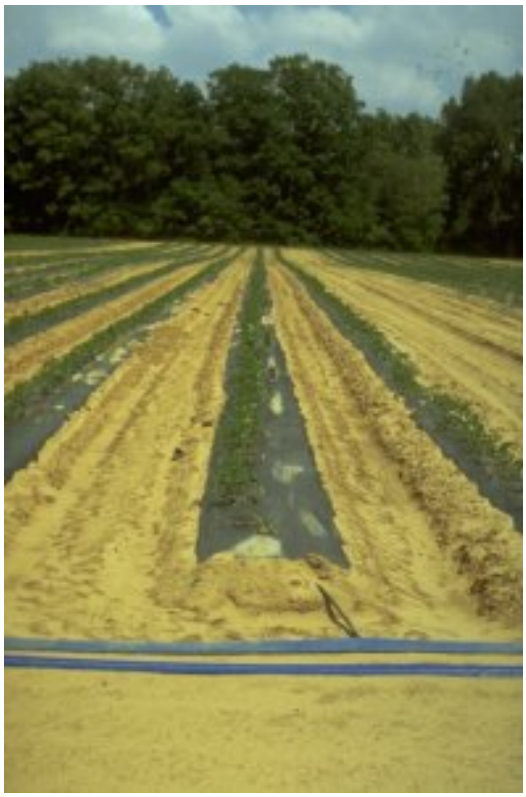
Ontario

Ministry of Agriculture and Food



Save water; choose water-efficient irrigation systems such as trickle irrigation in combination with mulch.

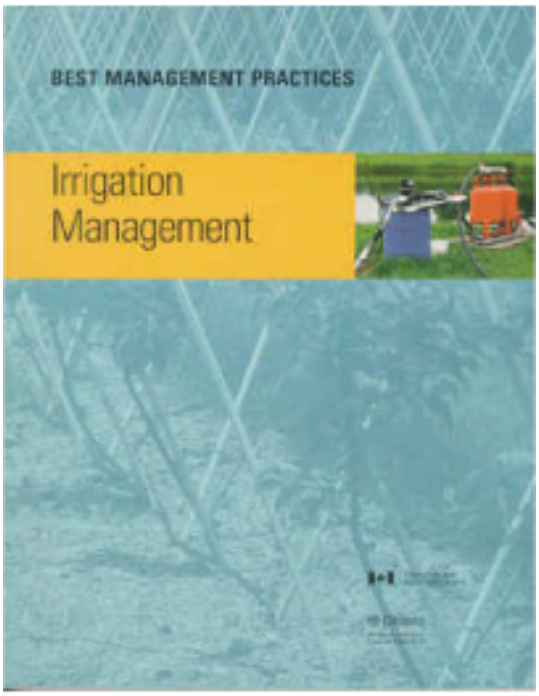
This site contains excerpts from the Best Management Practices, *Irrigation Management* book. The printed version can be ordered by clicking the link below. It is free to farmers.

Ordering Information

Series Information

** The symbol,  denotes a section or chart that is available in published form only. **

For more detailed information on irrigation management, refer to the following documents:



- Fresh Market Tomato Production. Ontario Ministry of Agriculture and Food Factsheet, Order No. 94-019
- Freshwater Intake End-of-Pipe Fish Screen Guidelines. Department of Fisheries and Oceans. FS 23-270/1995E
- Knotts Handbook for Vegetable Growers, 4th ed. Maynard, D.N. and George J. Hochmuth. 1997. Order
- Modern Fruit Science, 10th ed.Childers, N.F., J.R. Morris, and G.S. Sibbett. 1995. Horticultural Publications, Gainesville, FL. Order
- How to Prepare for Irrigation During Water Shortages. Ontario Ministry of Agriculture and Food Factsheet, Order No. 99-023.
- Water Management: Best Management Practices book. 1994

The production of the BMP series of books has been a cooperative effort of Agriculture and Agri-Food Canada, Ontario Ministry of Agriculture and Food, and the Ontario Federation of Agriculture.

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Introduction

Potentially high-value crops such as fruits, vegetables, tobacco, sod and nursery stock must be of top quality to win acceptance in the marketplace. Attaining quality requires timely management decisions - especially of crop production inputs.

Water, in the form of precipitation or irrigation, is one of the most critical crop inputs. Natural rainfall can be unpredictable. Water must be supplied in sufficient quantity, of desired quality, when the crop needs it. By controlling your crop's water supply, you are controlling an essential production variable.

Beyond good soil management techniques, irrigation is the best management technique available to meet your crop's water requirements when natural rainfall is inadequate. This book will help you plan and implement best management practices to fulfill water needs profitably, safely and in an environmentally responsible way.

But irrigation does not suit every operation. Its benefits must outweigh its costs. Consider the following criteria before purchasing, modifying or simply assessing your irrigation system requirements.

If You're Considering an Irrigation System

Criteria

Water Quality

- irrigation water must be free of contamination from pesticides (herbicides), heavy metals, organic solids, salts, nematode and other parasitic organisms
- water must be of desirable temperature and pH

Water Quantity

- sufficient volumes must be available on demand
- design should accommodate peak crop needs (for frost protection, design should be able to accommodate several consecutive nights' use)
- strategy should be in place to recharge limited volumes of water

Regulations & Legal Considerations

- these must be complied with before drawing water to irrigate
- Ontario Water Resources Act requires a Permit To Take Water from a surface or ground water source, or a combination of both, if the amount exceeds 50,000 litres (10,000 Imp gal) per day

Capital

- capital investment and operating costs can vary dramatically depending on system type, power sources, usage pattern, crop, field location and maintenance

Labour & Management

- irrigation systems demand differing degrees of input

Environmental Impact

- irrigating should not jeopardize the water cycle of a fragile ecosystem, nor interfere with quantity or quality of flowing water for downstream users

Safety

- an irrigation pond poses a potential hazard, especially in areas where there is easy access
- fencing should be provided, with Warning signs posted in high risk situations
- certain irrigation systems may carry an inherently high risk while in use, because of high operating pressure or potentially dangerous electrical energy

A large river like this one can be a suitable source of water. However, wetlands and smaller watercourses are not as well suited to irrigation.

Trickle irrigation systems can deliver water to where the crop needs it, efficiently and economically, as shown here with high-density apples on M9 rootstock.

Each system demands differing degrees of labour input.

Taking large amounts of water from groundwater can lower levels in wetlands, small streams and nearby wells.

Available in Published Version of Irrigation Management

Benefits of Irrigation

- Establishment
- Growth and Vigour
- Flower-setting and Fruit Development
- Quality
- Special Application

Protecting Water Resources

- Summary of Environmental Concerns - *chart*

Design, Materials and Management

- Industry Standards for Measurement

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Water Sources

When you draw water for irrigation, you must ensure there are no long-term implications for the local environment, and no short-term interference with other uses. More specifically, you need to know:

- an estimate of how much water might be needed
- how continuous the supply is (or the recharge rate), especially during the time of need when conditions are the driest and supplies usually the lowest
- that the quality of water matches the needs of the crop to be irrigated
- how the location of the water supply impacts the design and cost of the system, i.e., horizontal distance and vertical lift
- the repercussions if adequate water isn't available
    - a shortage of water with micro-irrigation systems can be disastrous
    - running out of water while protecting a crop from frost can also be disastrous - e.g. small fruit or berry growers should have a water inventory capable of use for several consecutive nights of frost protection
- whether the amount of water you're taking is environmentally sustainable
    - the effects on fish and fauna - a large suction inlet cuts down on water velocity entering the intake pipe, and allows fish to escape in special circumstances
    - effects on quality and quantity of water in adjacent bodies of water
    - effects on the water table.

Be sure you know the recharge rate of your water supply - particularly during periods of greatest need and lowest supplies.

The published version of Irrigation Management describes types of water sources such as lakes, rivers and streams, water wells and ponds, and how they may be affected by irrigation.

Ponds

Construction specifications, water source and permit information is provided for several types of ponds.

Dugout Pond

Construction

- storage volume determined by how much is excavated
- side slopes 2:1 (horizontal:vertical) or flatter
- depth 10 feet (3m) or more if possible (to help with weed control)
- best source is where there's a shallow water table in a pervious soil

Main Water Sources

Direct Rainfall

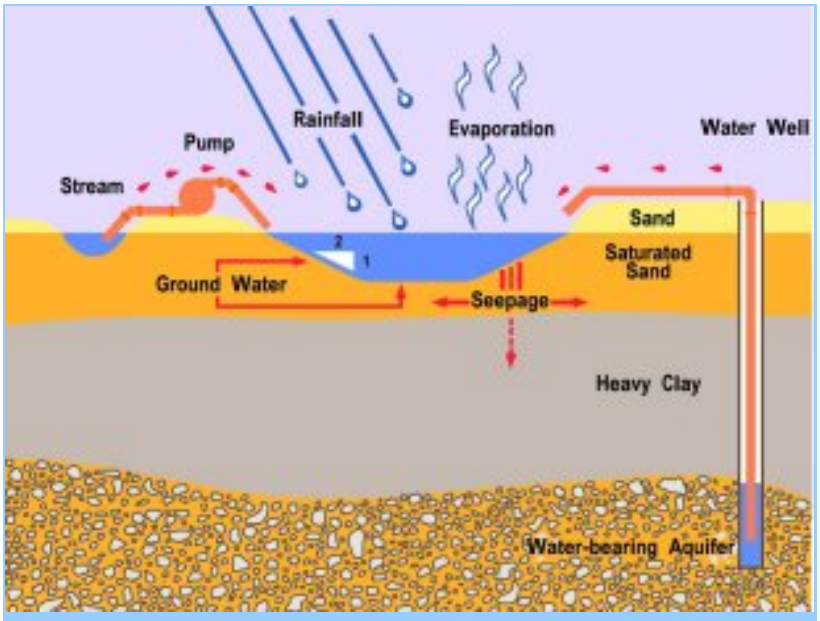
- not adequate to fill or replenish storage (approx. 39 in/yr [1,000 mm]

Ground Water

- can be a good source - must be identified by experience within the region, or dig a test hole and observe over one summer season to determine dependability (recharge rate and static water level)

Tile Drainage System

- generally not adequate as a total supply unless it's tapped into a spring that continuously supplies water
- main supply of water in the spring
- quality of water can be a concern depending on activities on the fields that the system services



Dugouts can be replenished by many sources. From ground water, ponds can gain water from tile drainage, wells and ground water flow. Water can be pumped from lakes, rivers, streams and ponds. Ponds can also collect rainfall and snowmelt.

Artesian Spring

- excellent source of water if quantity is adequate
- not very common to most of Ontario

Water Well

- can be a total or partial source of water if volumes are available to meet the need
- adds considerable cost to system if well has to be installed
- if pumped heavily, water level in neighbouring wells may be affected

Rivers, Streams, etc.

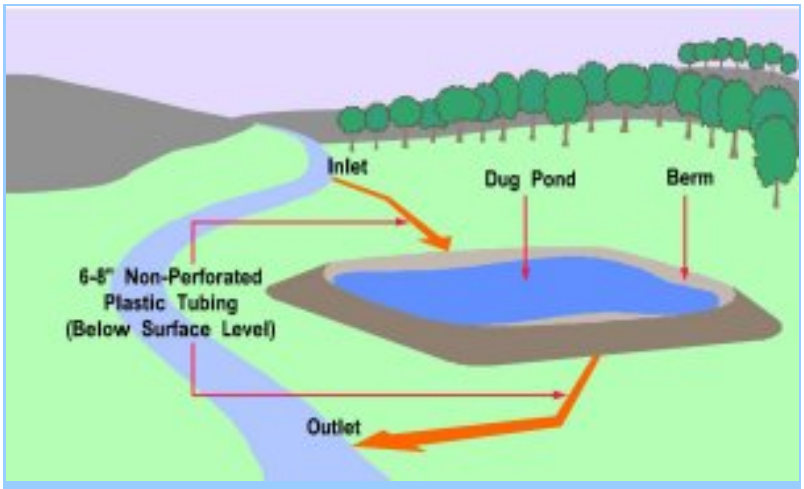
- excellent source of water if accessible and flows are adequate
- pond can be replenished by pumping water from stream into pond at a controlled rate so as not to affect other users and uses of stream, and at time of year that will have least impact (spring)

Bypass Pond

Construction

- storage volume is determined by how much is excavated
- side slopes are 2:1 (horizontal:vertical) or flatter
- depth is 10 feet (3m) or more if possible (to help with weed control)
- locate adjacent to stream
- available space is sometimes limited if stream is located in valley

Main Water Sources



A properly designed bypass pond can be replenished by diverting water (<20% of flow) from a stream. Bottom-draw outlets will release only deeper, cooler water, which benefits cool- and cold-water fish like salmon and trout.

Rivers, Streams, etc.

- excellent source of water if accessible and flows are adequate
- pond can be replenished by diverting water from stream into pond (through a diversion channel or pipe, at a controlled rate so as not to impact other users and uses of stream [<10% of flow])
- you can select water with this system not only for quantity but also quality
    - after a storm, when water can be murky with sediment, etc., you can close diversion until water is cleaner
- for intermittent streams, pond needs to be sized bigger to give enough storage between runoff events

Impoundment Pond

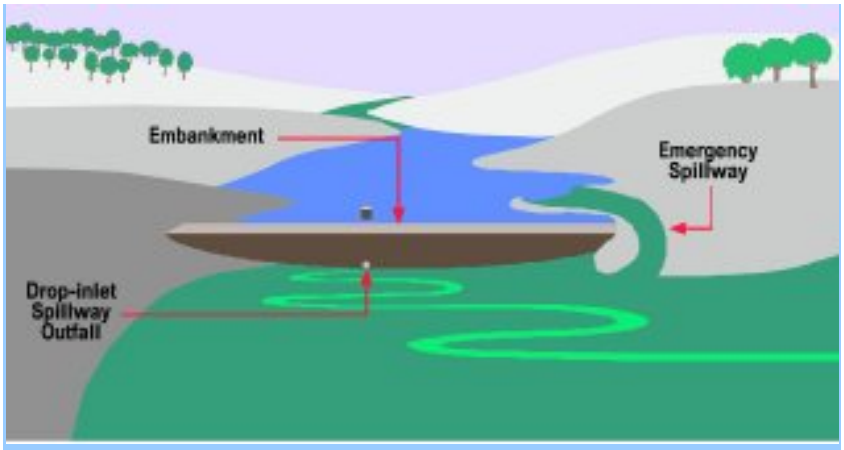
Construction

- a dam is built across an intermittent stream, a draw or a valley (but not in a continuous-flow stream)
    - involves specialized construction: layers of impervious soil are placed between two banks and compacted to form the dam
    - capable of holding back large volumes of water depending on the valley characteristics (slope, elevations, etc.)
- water is held back until it reaches a certain level, and excess water must be passed through an overflow device (spillway)
    - spillways can be made of concrete, steel or plastic, and must be sized according to the predicted flows
- the entire system must be designed according to sound engineering principles and built with equal attention - a failure could cause severe downstream damage
- can be very costly

Note: Dams on continuous-flowing streams can cause serious problems to fish movement and habitat. Approval for on-stream dams is rare because of the potential negative impacts. Dams across ravine areas that don't have a stream in the bottom are the best option.

Main Water Sources

Runoff



Impoundment ponds require a dam constructed of impervious layers, and a spillway to outlet excess water.

- runoff is the main source of water, and is prone to quality problems depending on the land activities in the runoff watershed
- runoff dams are dependent on surface runoff in the spring to fill; additional runoff in the summer isn't dependable or continuous

Rivers, Streams, etc.

- excellent and dependable sources of water
- even though a dam usually can't be built across them, they can be used as a source of water by pumping into the pond if runoff is not adequate

Permits That May Be Required - All Pond Types

Permits are required to build or modify any pond type.

- Permit To Take Water, >50,000 litres (10,000 Imp gal) per day
  - not only for irrigation but also to fill or refill pond
- Permit to Construct from Conservation Authority if site is in the designated floodplain
- Permit to Construct from Ontario Ministry of Transportation if close to a highway
- remember, you cannot build on a stream!
- permit may be required within Niagara Escarpment Commission area.

Available in Published Version of Irrigation Management

Types of Water Sources

- Lakes, Rivers and Streams
- Water Wells

Ponds

- Farm Pond Water Capacity - *chart*
- Seepage Control - All Pond Types
- Algae Control in Irrigation Ponds

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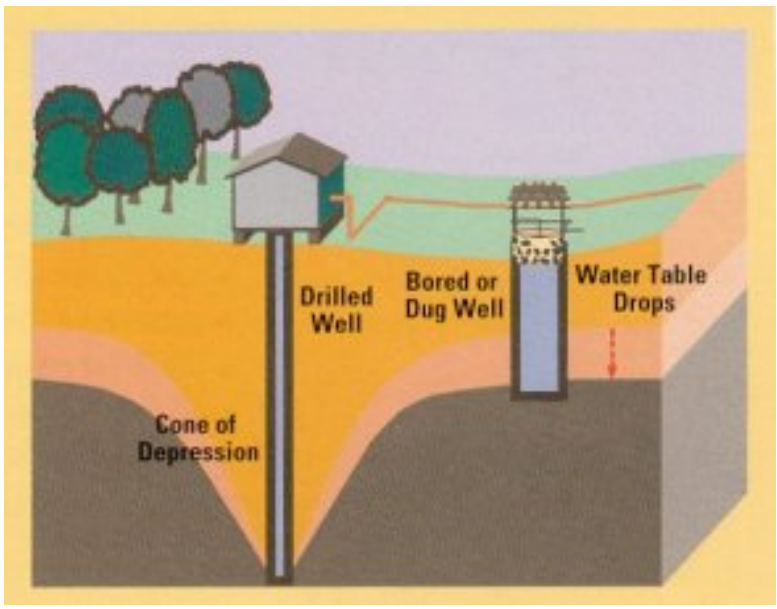
Taking Water: Permits and Legislation

To protect your rights and the rights of future water users, federal, provincial and local governments have created laws and guidelines that ensure an abundant supply of clean water.

Most of the water-related laws and guidelines that can directly influence the use of irrigation on your farm are listed in the published version of this book. If you have concerns or questions regarding irrigation management on your property, be sure to contact relevant government agencies, and be aware of bylaws in your area.



When large amounts of water are taken in a short period of time, a cone of depression is created in the area of deeper wells. This can cause neighbouring wells to run dry.

Permit to Take Water

A Permit to Take Water is required if you're taking in excess of 50,000 litres (10,000 Imp gal) per day for any use other

than general household activities or livestock watering. The permit is issued under the *Ontario Water Resources Act.*

The permit's purpose is to ensure all water users and the aquatic environment get their fair share while protecting the resource. To get an application for a permit, contact your local office of the Ontario Ministry of Environment. See the blue pages of your telephone directory for the office nearest you.

Harvest water during peak or high flows so that you won't need it at low flows.

If you plan to use greater than 50,000 litres per day from surface water, such as rivers, streams, creeks and irrigation ponds supplied by surface waters, **you will be required to provide the following information** with your application for a Permit To Take Water:

- the flow rate of the river, stream or creek (preferably measured during summer)
- the estimated daily rate of water used
- the volume of water required for irrigation
- a completed application form

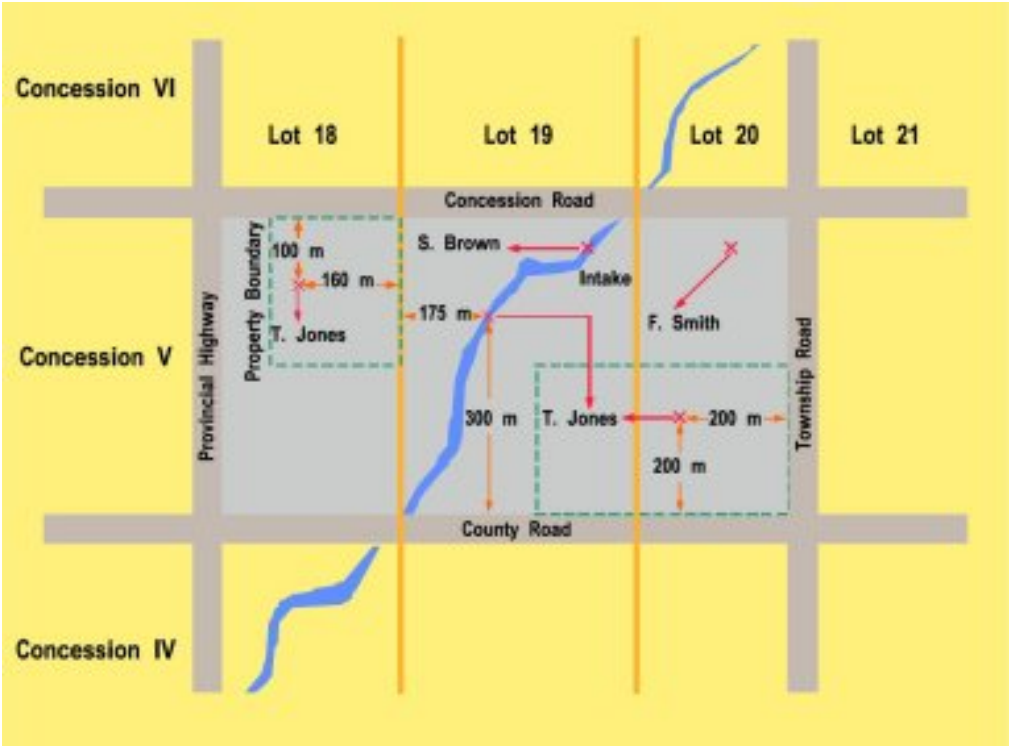
Note that the best management practice for replenishing ponds from surface water is to "harvest" the water during peak or high flow. This helps to prevent taking water from watercourses at lowest flows.

If you plan to use greater than 50,000 litres per day from ground water, either from a well, a pond replenished from a well or an excavated pond replenished directly by ground water, **you may be required to provide the following information** with your application for a Permit to Take Water:

- a completed Permit to Take Water application form
- a location map (see map below)
- water well records within the survey area
- details on pumping equipment and intake levels
- information on subsurface conditions, e.g., pits, drill holes or other excavations
- pumping test - indicate water level before and after maximum water-taking applied for and time taken for water level to recover.

The above information may be sufficient if ministry officials consider yours to be a low risk situation. Low risk means that there is minimal impact on surrounding users. If the taking is not deemed low risk, further information may be required by the Ontario Ministry of Environment as determined by the specific situation.

For more information about some of the Legislation and Guidelines Protecting Water Resources, see the published version of the Best Management Practices Book *Water Management*.



Location maps for Permits To Take Water require general location (lot, concession, direction) as well as water supplies and wells within 0.3 mils (0.5 km) of your source of water. The map, together with estimates of water-taking and supply, will help in the assessment of potential impact on neighbouring users.

Available in Published Version of Irrigation Management

Some of the Legislation and Guidelines Protecting Water Resources - *chart **

** A similar version to this chart is available online in the Best Management Practices, Water Management book.*

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Ontario

Ministry of Agriculture and Food

Scheduling: Knowing When and How Much to Irrigate

The goal of irrigation is to provide a crop with the right amount of water, when the crop needs it for maximum crop response, at the lowest cost and with least impact on the environment.

To do this effectively, it's worth looking at some basic principles, such as:

- how water flows through, over, and around your cropland
- how soils provide moisture to crops
- how much water crops require and when they need it
- how to estimate and schedule crop water requirements practically and at low cost.

This section explains:

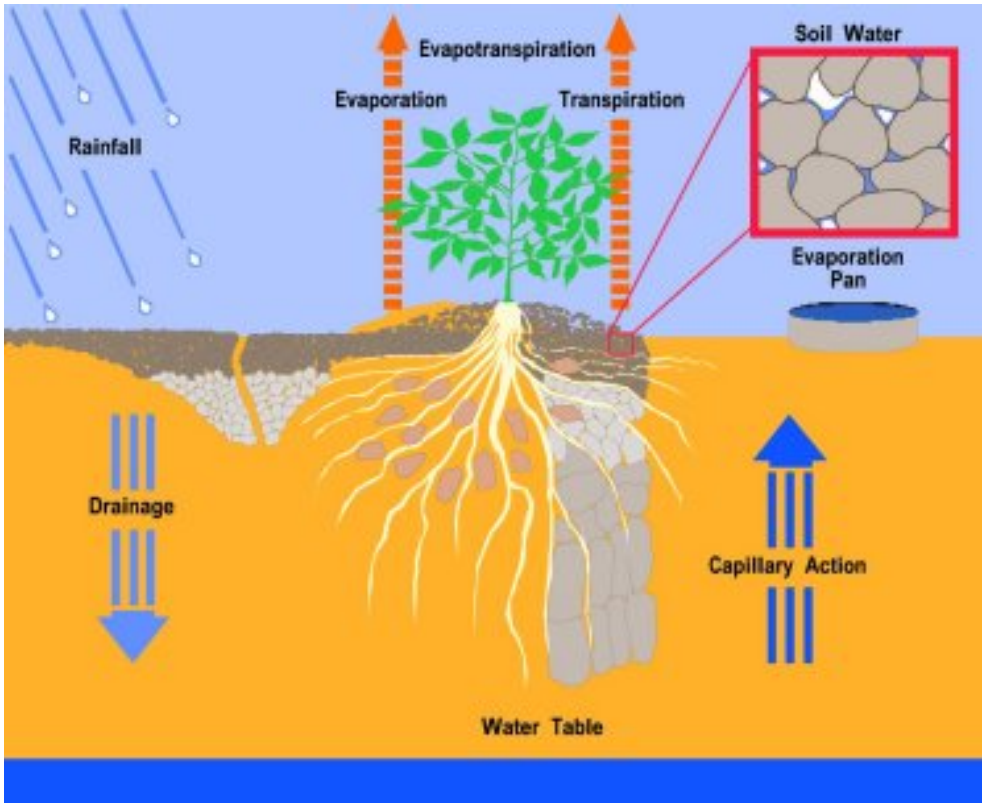
- when to irrigate
- how much water your crop requires, using practical and accurate methods
- how to change the amount of water applied if soil types change across your farm
- how to account for rainfall when you estimate crop water needs.

To irrigate effectively, you need to know how much water your crop needs, and when it needs it.

Water Cycle

Knowing how water moves through cropland can help you use irrigation water more effectively and with less risk to water

sources.



Water is added to cropland as snow, snowmelt and rain. In a typical field, most of this water will eventually be evaporated back to the atmosphere (66% from April to October). About 25% of it will run off the soil surface to streams, creeks, drains, lakes and ponds.

The remaining 9% of this will enter ("infiltrate") the soil. This soil water can flow through the soil to ground water, be stored as soil moisture, or is transpired by plants back to the atmosphere. The ground water will replenish the soil water table (shallow aquifers), percolate to deep aquifers, or flow back to surface waters such as streams and creeks.

Irrigation is applied to crops just before the combination of evaporation and transpiration (evapotranspiration) exceeds the available soil moisture supplies to meet crop requirements. The fate of irrigation water, particularly with overhead sprinkler systems, is similar to that of falling precipitation. The fundamental difference is that water is taken from local surface or ground water sources. The risk to these resources is taking or wasting too much water when supplies are low.

Water Balances: Rainfall and Crop Requirements

Most of the province's irrigation occurs in Southern Ontario, where average annual precipitation ranges from about 26.0 to 40.2 inches (660-1020 mm). In Southwestern Ontario, crop water requirements may be 20 to 24 inches (500-600 mm) during the growing season, but precipitation during the same period averages only 12 to 16 inches (300-400 mm). This results in a water deficit for the crop in an average year. Unfortunately, years of below-average rainfall also occur, causing even greater moisture deficits.

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Irrigation Scheduling

Irrigation scheduling is the process of planning and providing crops with the amount of water needed, when they need it. It involves monitoring, record-keeping, and calculations to determine field water capacity, losses and gains. Ultimately the producer compensates for net losses with irrigation. This system is based on known daily water losses by ET for various crops in different growth stages.

Benefits of Scheduling

- increased yields and quality; better returns on investment of irrigation equipment
- more efficient use of water resources
- more efficient use of equipment, management time and labour
- avoids delaying irrigation until moisture stress has occurred and damage to yield and quality is irreversible, i.e., optimizes application timing
- reduces the possibility of excess moisture that will lead to leaching or runoff because the exact water-holding capacity of the particular soil is known

Factors in Scheduling

- specific infiltration rates and available water-holding capacities of the various soil types must be known
  - some calibration work may have to be done
  - you may have to measure the performance of the soil using known quantities of soil and water
- crop rooting depth - deeper-rooted crops will need less frequent but deeper irrigations than shallow-rooted crops
- the probability of rainfall - this affects frequency and amount of irrigation needed
- overwatering a field can cause excessive leaching or runoff, which can lead to a deterioration in soil structure

The physical properties of your soils must be known to help make irrigation scheduling work effectively. The technician in this case is taking soil samples to measure water-holding capacity.

The physical properties of your soils must be known to help make irrigation scheduling work effectively.

Ranges in Available Water Capacity and Intake Rate for Soil Textures

Soil Texture	Available Water Capacity (in. of water/in. of soil) (mm of water/ mm of soil)		Intake Rate			
			(in/hr)		(mm/hr)	
	Range	Average	Range	Average	Range	Average
Sands	0.05-0.08	0.065	0.5-1.0	0.70	12-25	18
Loamy Sand	0.07-0.10	0.085	0.3-0.8	0.55	7-20	14
Sandy Loam	0.09-0.12	0.11	0.3-0.8	0.55	7-20	14
Loam	0.13-0.17	0.15	0.3-0.8	0.55	7-20	14
Silt Loam	0.14-0.17	0.16	0.2-0.3	0.25	4-8	6
Silty Clay Loam	0.15-0.20	0.18	0.2-0.3	0.25	4-8	6
Clay Loam	0.15-0.18	0.17	0.2-0.3	0.25	4-8	6
Clay	0.15-0.17	0.16	0.1-0.25	0.20	2-6	4

Considerations for Applying Irrigation Water

Avoid wasting water during application. Be aware of the water intake rate of the soil. This is the rate at which water infiltrates the soil and it determines how much water to apply per hour. The table above lists the maximum rate of water to apply per hour for various soil types. Coarse-textured soils have a higher water intake rate than fine-textured soils. Rain or irrigation guages should be placed in the field to help you determine how much irrigation water you've applied.

Most crops have certain growth stages, during which drought stress can severely reduce yield and/or quality. While adequate moisture is desirable at all growth stages, irrigation is especially important during the critical growth periods. Using simple monitoring methods and calculations, scheduling can make irrigation more timely, precise and less wasteful.

Available in Published Version of Irrigation Management

Soil Water

- Rate of Water Movement into Soil - *Chart*

Crop Water Requirements

Irrigation Scheduling: Methods of Determining Need

- Soil Moisture
  - Feel Method "Feel Testing Soil" - *Chart*
  - Tensiometer
  - Other TechnologiesSeepage Control - All Pond Types
- Plant Stress Indicators
  - Visual Symptoms
  - Leaf Reflectance
  - Leaf Temperature
  - Instruments
- Evapotranspiration
  - Methods of Estimating Evapotranspiration: The Water Balance Method
    - Irrigation Depth - Horticultural Crops and Field Crops- *2 charts*
    - Irrigation Scheduling Worksheet (Steps 1-7)
    - Crop Factors for Vegetables and Fruit Trees - *2 charts*
    - Average Maximum Daily ET Values - *chart*
- Scheduling by Computer

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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 section, 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.

Sub-irrigation and controlled drainage provide water to plants from below the root zone.

Sprinkler irrigation systems are designed to distribute water over the entire soil and plant surface of the field.

Micro-irrigation systems apply water to the soil around each plant.

Sprinkler systems are the least water-efficient. Water can be readily lost to wind, evaporation and runoff.

For many people, the most important variable in a system choice is cost.

Comparative Purchase Costs of Irrigation Systems

Irrigation System*	15 Acres	50 Acres	100 Acres
Hand-Move Portable	$1450/ac 3 moves 5 ac irrigated move	$750/ac 5 moves 10 ac irrigated/move	NA
Semi-Permanent	$1400/ac 3 moves 5 ac irrigated/move	$720/ac 5 moves 10 ac irrigated/move	NA
Solid-Set	$3300/ac	$2600/ac	$2400/ac
Fixed-Volume Gun, Hand-Move	$1500/ac	$1400/ac	$1300/ac 81 moves
Traveling Gun	$1400/ac	$940/ac	$500/ac
Traveling Boom	$1600/ac	$1050/ac	$560/ac
Centre Pivot	NA	$700/ac	$570/ac only irrigates 89 acres

Lateral Move	NA	$930/ac	$800/ac
Micro-Irrigation Disposable Tape	$100 ac. ($300/ac/yr. to replace tape)	$800/ac	$700/ac
Permanent Tubing **15-yr life**	$2800/ac	$2500/ac	$2400/ac

Assumptions: All pricing based on close water supply and minimal suction life. Fields are relatively flat and shaped such that main supply lines are minimal. The dollar values presented here are estimates from 1995.
*Power supply not included.
To convert to costs per hectare, multiply cost by 2.48.

The techniques of each system are quite different, however, and have inherent advantages and disadvantages that may influence your irrigation system choice.

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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

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

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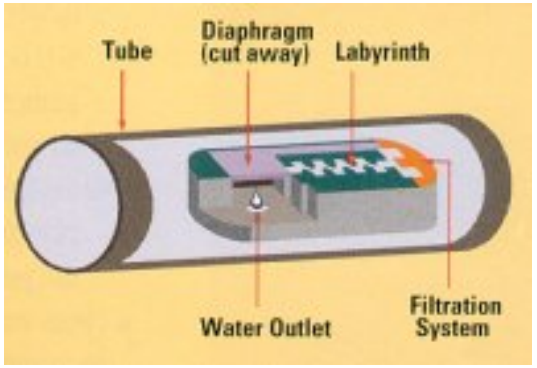
Micro-Irrigation *(also called drip or trickle irrigation)*

Micro-irrigation systems consist of a water source, pump, filtration system, flow meter, mainline, header lines, pressure reducers (if required), lateral lines and emitters.

Design & Hardware

- the basic micro-irrigation system components include a water source, pump, filtration system, flow meter, mainline, header lines, pressure reducers (if required), lateral lines and emitters
- pumps are smaller, less power is required, less energy is used, and the water conveyance lines are smaller
- lateral lines are made up of small-diameter flexible plastic pipe (0.4-0.6 inch [10-15 mm] diameter), and when laid out are left there from season to season
    - emitters are manufactured right inside or can be inserted into the pipe
    - some lateral lines are a disposable-tape type of line are are replaced yearly; longer-life tapes (up to 7 years) are available at higher cost
- large selection of emitters (the equivalent of the sprinklers in other systems)
    - can be of a spray, drip or trickle type, depending on the zone to be wetted
    - can be in-line or offset
    - emitter(s) can be positioned at each plant (e.g., apple, peach orchards) or spaced closely together 8-24 inches apart (200-600 mm) to water a continuous row (e.g. raspberries, blueberries, strawberries, tomatoes, melons etc.)
- 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 fields 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 usually needed
- 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.

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

How It Works

- system supplies a small amount of water (1/2 US gas/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, vegetables 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

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 chemigation and 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
+ does not remove crop protection materials from leaf canopy or maturing fruit
+ operating costs are relatively low
-- cannot be used for frost protection
-- root systems don't usually develop fully, so water supplies must be dependable - 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 - lines can get tangled in equipment

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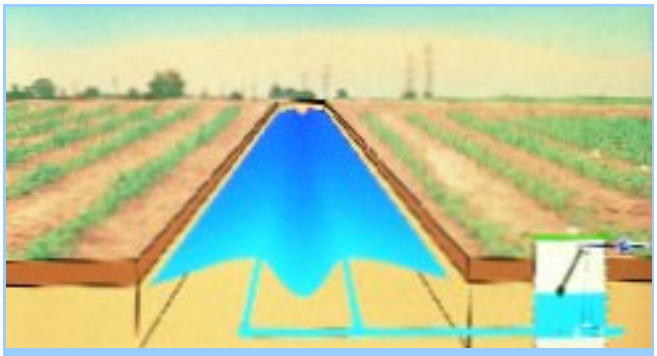
Controlled Drainage / Sub-Irrigation



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.

A subsurface irrigation system manages the water table to provide optimum soil water conditions for crop growth. The concept is to prevent rather than relieve moisture stress. The water table is kept 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.

Available in Published Version of Irrigation Management

Sprinkler Irrigation

- Fixed Sprinkler Systems
  - Hand-move portable system
  - Semi-permanent system
  - Solid-set permanent system
  - Fixed-volume gun hand-move system
- Mobile Sprinkler Systems
  - Traveling gun system
  - Low-pressure boom traveller system
  - Centre pivot system
  - Lateral move system

Controlled Drainage / Sub-Irrigation

Irrigation Pumps

- Centrifugal Pump
- Turbine Pumps
  - Submersible Turbine
  - Line-shaft Turbines Pumps

Power Sources

- Electric motors
- Internal Combustion Engines
  - Power Requirements, Water Horsepower, Fuel Cost Comparisons

Hardware

- Pipe
  - Aluminum, Plastic
- Pipe Connections
  - Knob and Latch, Ball and Socket
- Sprinklers
  - Material

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Best Management Practices for Crop Production

The best management practices in this section provide tips that increase crop productivity and quality and, where technology is available, save water. Presented here is an overview of water efficiency. See the printed version of this book for tips on the best systems and critical irrigation periods for key irrigated crops, from fruit trees to nursery stock.

Water Efficiency

Here are some general best management practices for most crop operation using irrigation:

Match crop to suit soil conditions

- if your soils are droughty and the crop considered is highly responsive to irrigation, choose another crop or another site

Build your soil's organic matter: add manure and compost, or grow plowdowns.

Build healthy soils - you want water to infiltrate and be available for crop use

- add organic matter (manure, green manure, compost, cover crops): your soil's structure will improve and the amount of water available to your crop will increase
- avoid compaction: don't work wet land, especially heavier soils
- reduce tillage: less tillage means less drying and less organic matter loss
    - you may wish to try reservoir tillage: it holds water a the soil surface for infiltration
- with reduced tillage and higher organic matter, earthworm populations will increase

Irrigate efficiently

- harvest water from watercourses during peak flows, or from ground water when water table is high
- sprinkle irrigate when winds are less than 3 mph (5 km/hr)
- choose drip irrigation next time you upgrade
- apply the right amount of water when the crop needs it - use irrigation scheduling
- avoid irrigation during the heat of the day

Reduce water loss; use organic mulches

Reduce water loss from crops and soil (evapotranspiration)

- plant windbreaks or wind strips to slow drying winds
- plant perennials into chemically killed sod
- use dwarf grasses between orchards and nursery crops
- schedule short-season crops for spring or fall
- manage crop residues to reduce runoff, increase infiltration so that they can act like a mulch
- space plants to cover soil surface quickly
- use plastic or organic mulches
- control weeds early
- mow sod and cover crops regularly
- some tillage can be beneficial under dry conditions. A soil mulch layer can reduce soil evaporation in some circumstances, e.g. vegetables on muck soils, and strawberries on mineral soils.

Use plastic mulches to save water.

You may choose not to irrigate because of increased costs that outweigh the potential benefits. Cost/benefit is directly related to soil type, site location, season, planting density, training system, etc. For example, a strawberry grower may choose to go without a system because of soils with good moisture-holding capacity. If your operation is located in a climatically preferred region and on a good site, frost losses totaling a few thousand dollars in one out of four years may be acceptable compared to an investment of $50,000 to $100,000.

See published version for best management practices charts that summarize some of the documented benefits of irrigation. There are charts for the following crops: fruit crops, vegetable crops, tree nut crops, tobacco, ornamentals, and sod.

This version includes sample charts for apples, lettuce and onions.

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Fruit Crops

Reducing depth to 20' (6.0m), varies with soil type, structure and rootstock

Code:
seldom expect response
some response 30-60% of time
expect response most years (75%)
expect response 9 years out of 10

Amount of water required:

- up to 8 Imp gal/mature tree/day (36.4 L/day) during July and August
- 1" (25 mm) every 14 days to maintain 50-100% available soil moisture
- 1" (25 mm) every week during July and August

Crop	Benefits of Irrigation	Critical Irrigation Periods	Commonly Used Systems	Best Management Practices / Considerations
Apples* low to medium density on vigorous or semi-vigorous root systems; high density systems (M26, M9 root stocks or equivalent)	• increased fruit size and yield • more fruit bud initiation • less biennial bearing • reduces probability of bitter pit • trees are in better condition going into dormancy • better growth and development of nursery stock • moderation of June drop	• May-September (trickle) • bloom (through cell division stage) • fruit bud initiation (June) • fruit swell (August-September)	• travelling gun • trickle • fixed-volume gun	• large volumes of water applied over short time periods are normally applied with a gun • more important on fully dwarfing rootstock • use short wettings to avoid scab and fireblight spread • uniform soil moisture may reduce bitterpit • moderate or excessive summer pruning under drought conditions (without irrigation) may have a negative effect on crop volume and finish • do not root prune on droughty soils unless irrigation is available - the added stress may also affect winter hardiness • mulch to save water

* Where a water tank is used, apple trees in medium to higher density plantings on size-controlling rootstocks will not likely respond to < 20 Imp gal or 100 L of water during extended periods of drought. Standard trees usually require at least 50 Imp gal or 250 L of water per tree to relieve stress during extended periods of drought.

High density apple systems are quite suitable to trickle irrigation. Note the added benefits of mulch for water conservation. A nematode-resistant dwarf perennial rye sod is between tree rows.

Gummosis (heat spot) of plum can be more prevalent under dry growing conditions.

Avoid sweet cherry cracking - do not sprinkle irrigate after fruit colour. Water absorption leading to cracking takes place primarily through the skin of the ripe cherry.

General Notes On Irrigation For All Fruit

Irrigation improves plant establishment, nutrient use, bearing area and plant health. It can also be used for frost control (sprinkler), fertigation and chemigation.

Overhead irrigation is recommended for frost protection, chemigation and evaporative cooling. Trickle irrigation is more suitable for fertigation than overhead sprinklers, and will cause fewer infections of scab, fireblight, brown rot, Botrytis fruit rot, etc. Some measure of frost protection may be gained fro under-canopy, low-trajectory sprinkler irrigation systems. They are not probably best suited for high density plantings not taller than 6.5 feet (2m), but have not been fully evaluated in Ontario.

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Vegetable Crops

Shallow-rooted Vegetables:
rooting depth of 2-3' (0.3-0.6 m) in most soils

Code:
seldom expect response
some response 30-60% of time
expect response most years (75%)
expect response 9 years out of 10

Amount of water required:

~approx. 1" (25 mm) per week during vegetative growth
~approx. 1.5-2" (40-50 mm) per week during critical periods

Crop	Benefits of Irrigation	Critical Irrigation Periods	Commonly Used Systems	Best Management Practices / Considerations
Lettuce	• improved germination of direct-seeded lettuce	• head formation and sizing	• hand-move port. • low-pressure boom	• irrigation important for seeded lettuce, especially in hot weather
Onion	• larger bulbs • more single centres	• bulbing and enlargement	• hand-move port • travelling gun • sub-irrigation	• requires 1-2" (25 mm) weekly • excess water as the bulbs mature will result in thick necks, immature bulbs, and storage problems - decrease moisture supply gradually as bulbs mature

Both sprinklers and irrigation guns are appropriate for onions. Irrigation of onions may be necessary on shallow muck or mineral soils.

Available in Published Version of Irrigation Management

Best Management Practices for specific crops are included in the printed version of this book. They summarize many documented benefits of irrigation, including when and how to irrigate. Crops included:

- **Fruit Crops:** Apple, Peaches & Nectarines, Pears, Plums, Cherries, Apricots, Grapes, Lowbush and Highbush Blueberries, Raspberries, Strawberries, and Other Bush Berries
- **Vegetable Crops:** Beans, Beet, Cole Crops, Carrot, Celery, Cucumber, Garlic, Lettuce, Onion, Pepper & Eggplant, Potato (sweet & regular), Sweet Corn, Tomatoes, Asparagus, Watermelon
- **Tree Nut Crops:** Filbert/Hazelnut, Heartnut & Sweet Chestnut, Walnuts & Pecans
- **Tobacco**
- **Field-grown Nursery Stock**
- **Container-grown Nursery Stock**
- **Sod**

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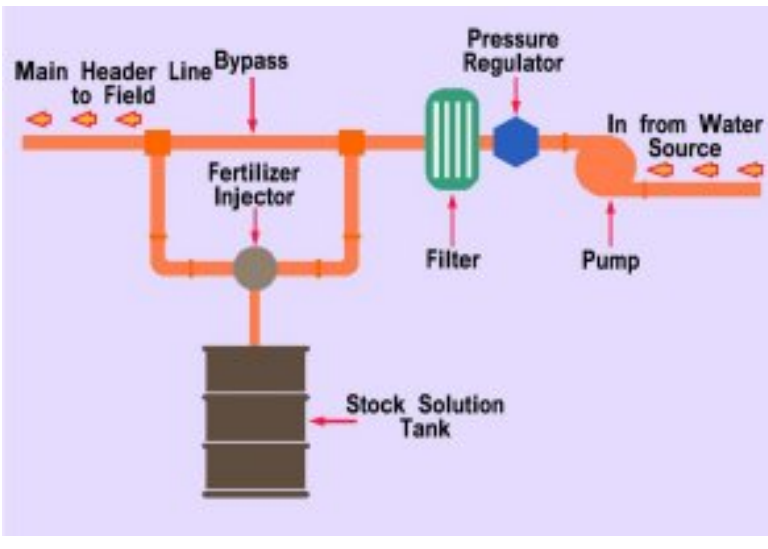
Special Applications

Supplying water for crop use is not the only useful function of an irrigation system. It can also be used to apply crop protection materials to high-value crops. Frosts, sandblasting and excessive heat can be controlled in some situations. Also, in selected crops, productivity can be increased and quality improved by applying crop nutrients with irrigation water through "fertigation". Fertigation is normally done using established drip (also known as micro-irrigation or trickle) systems.

Fertigation, chemigation, evaporative cooling, wind erosion control and frost protection are all presented in this booklet. These best management practices require careful management to ensure effectiveness, water efficiency and protection of the environment.

Fertigation of Field Vegetables and Tree Fruit

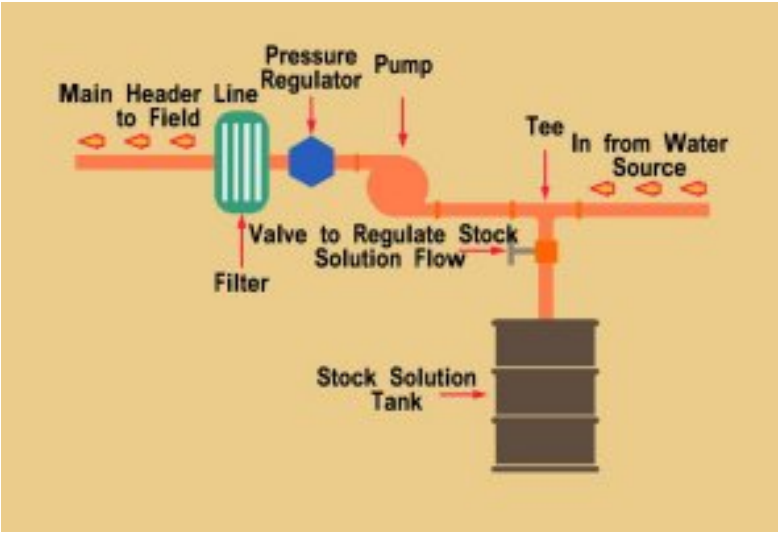
Drip irrigation and fertigation are relatively new practices for fruit and vegetable growers in Ontario. They provide a very efficient method of applying irrigation water and nutrients, and can be used to increase yield and quality of certain fruit and vegetable crops.



Fertigation System Design

There are many systems available to inject fertilizer solutions into irrigation water. The most accurate is a fertilizer injector (e.g., Anderson, Dosatron, Amiad etc.) that meters the fertilizer solution into the irrigation water at a pre-set ratio.

The fertilizer injector is the most accurate of fertigation systems.



Installing a tee is less expensive, and is usually on the suction side of the irrigation pump. It functions in a fashion similar to a fertilizer injector.

An alternative method is to install a tee on the suction side of the irrigation pump, with a hose leading to the fertilizer stock tank. The flow of fertilizer solution into the system is regulated with a tap or gate-valve. This setup isn't as accurate as a fertilizer injector, but is less expensive and should be accurate enough for most field situations.

Fertilizer Stock Solutions

Stock solutions are the concentrated fertilizer solutions that are injected into the drip irrigation system. To prepare the fertilizer stock solution:

- calibrate the system to determine how much stock solution is injected over the desired injection period - in most cases an injection period of approximately 1 hour is sufficient
- determine how much fertilizer material must be added to the stock solution to deliver the desired rates of nutrients on the land area to be fertigated.
- fertilizer materials must be mixed together in one stock solution tank, or separate solutions may be prepared for each fertilizer material and injected with a multi-head fertilizer injector.

An anti-backflow device such as a check valve prevents contaminated water from being drawn back into your water source.

Chemigation

Chemigation can be useful in strawberries if you have a solid-set low-volume sprinkler irrigation system.

Chemigation - the application of chemicals using irrigation technology - can be useful for strawberries, blueberries, and greenhouse and nursery crops.

Applying herbicides and pesticides in minute concentrations can save you time and money. However, it must be done with skill and **caution**. The main environmental concern is contaminated water entering a water source or ground water in the event of a spill or equipment malfunction.

Hardware

- spring-loaded check valve on pressure-side of pump to prevent backflow if pump stops
- foot valve to prevent backflow of water once it has entered pickup line from pond
- water source must be a pond that doesn't have an outlet, e.g., filled from a river, stream, or spring-fed -- don't operate directly from a municipal water source (mains)

- only solid-set, low-volume sprinkler-type setups using 1/8-, 1/10-, 1/12-inch nozzles, applying water in a uniform, even pattern over a field, are eligible for chemigation of strawberries

Safety

- pick a low-wind "perfect" spraying time for chemigation -- often early morning is appropriate
- don't allow anyone nearby or in the field while chemigating
- follow re-entry requirements and days to harvest as stated on the chemical label

If irrigation is to be carried out, do the chemigation at the end of the cycle, and quit immediately when it's completed.

Wind Erosion Control

Irrigation for wind erosion control is considered an emergency response only. Use other best management practices, such as grass wind strips, cover crops, residue management and/or windbreaks.

Many highly productive horticultural soils are prone to wind erosion. Dry loose soil is easily moved by wind.

Irrigation can provide some short-term emergency wind erosion control - or the final piece in an erosion control system. Water applied in advance of the wind event will help to hold soil. The success of this practice depends on:

- soil type
- amount of water applied (before and during windstorm)
- drying ability of the wind (relative humidity)
- duration of the wind event

This practice is best used in combination with other measures, such as residue management, grass wind strips or windbreaks.

Available in Published Version of Irrigation Management

Fertigation of Field Vegetables and Tree Fruit

- Fertilizer Materials Recommended for Preparation of Stock Solutions for Injection through Drip Irrigation - chart
- Fertilizer Requirements for Vegetables
- Recommended Fertigation Rates for Vegetable Crops Grown on Sand to Sandy-loam Soil Types - chart
- Fertigation Requirements for Tree Fruit
- Fertigation Scheduling for Vegetables and Tree Fruit

Chemigation

- Calibration
- Other Procedures

Frost Protection of Berry Crops

- Requirements
- Timing
- Problems

Evaporative Cooling of Strawberries

- Requirements
- Problems

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Analyzing the Costs and Benefits

Prior to investing in an irrigation system, an analysis of the financial factors should be made. In other words, will an investment in an irrigation system provide the desired returns?

This section provides a method to calculate the potential financial gain (loss) with the purchase and use of an irrigation system. The methodology is to estimate the annual costs and annual returns from the purchase and use of a specific system.

The analysis is completed on an annual basis. The annual cost for equipment that is used for more than one year is determined by spreading its net cost over its expected use period. For example, a pump purchased for $12,000, expected to be used for five years and then sold for $2,000, would have a net cost of $10,000. The annual cost would be $2,000 (i.e., $10,000 ÷ 5).

The cost/benefit analysis should be completed on a specific system. Before beginning, you should have a good knowledge of the component and installation costs of the system. In addition, an estimate of operating expenses such as fuel, labour, maintenance, etc. will be required.

Repair, Maintenance and Expected Life

The values listed in this chart are general averages. They should be used only as a guide to estimate repair, maintenance and average expected use for your system components.

	Repair & Maintenance % of Purchace Price	Average Expected Life (years)

Water Sources		
Well	0.5	25
Pond	0.5	15
Intakes		
Concrete Structure	0.5	20
Suction line screens	10.0	5
Pumps		
Turbine - Bowls	6.0	7
Turbine - Columns	4.0	20
Centrifugal	4.0	15
Submersible	4.0	15
Power Source		
Diesel	5.0	15
Gasoline	5.0	9
Propane	5.0	14
Electrical Wiring	1.0	25
Pipe and Tubing		
Steel: coated, lined and buried	0.5	40
Steel: coated and buried	0.8	20
Steel: coated and surface	1.5	12
Aluminum: surface	2.0	15
PVC: buried	0.5	40
Sprinklers	5.0	8
Tractors	7.5	15
Pipe Trailer	2.0	15

The actual cost/benefit calculations are completed using five worksheets, only the first one is provided here. See the published version of this Best Management Practices book for more details.

Worksheet 1: Water and Power Requirements

This general description worksheet is used to record and determine information required in other worksheets. It calculates the total amount of water required for a season. This is then used to calculate the number of hours the system will operate during the year. For systems using tractor or engine as a power source, the total fuel needed for one season is determined by the amount of fuel you estimate your power source will use in one hour of operation and the total annual hours of operation.

The pumping rate is the US gallons of water per hour that can be irrigated by the system being evaluated. The pumping rate may need to be adjusted from the rate specified for factors such as water depth and distance to the field.

1. Acres to be irrigated..... _____

2. Average gross inches per acre applied annually..... _____

3. Total acre inches applied annually (line 1) X (line 2).....= _____

4. Pumping rate (US gallons per hour)..... _____

5. Operating hours per year [27154* X (line 3)] / (line 4).....= _____

6. Energy requirements

   a. Stationary pump or tractor (line 5) X (litres of fuel per hour of use).....= _____

   b. Electric Motor (line 5) X (kW: hydro/hour).....= _____

* 27,154 US Gallons (22,610 Imp gal) are required to put one gross inch of water on one acre of land.

Available in Published Version of Irrigation Management

Five worksheets to calculate actual cost/benefit:

- Worksheet 1: Water and Power Requirements
- Worksheet 2: Annual Ownership, Repair and Maintenance Costs
- Worksheet 3: Annual Operating Expenses
- Worksheet 4: Cost / Benefit Summary
- Worksheet 5: Break-even Calculations

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