YOUNG AGRARIANS

# WATER USE & DRAINAGE MANUAL

## FOR LANDOWNERS AND FARMERS IN METRO VANCOUVER

Edition 1.0

A COLLABORATION WITH

SPEC

# FIRST NATIONS ACKNOWLEDGEMENT

"The wisdom of our ancestors is echoed in the prayers, songs, stories, dances and ceremonies that honour the Sacred Nature of water. They tell of the spirit of water as a life giving force, and recognize the relationships and responsibilities between the waters and the Peoples, charting the course for actions we are bound to take to protect and safeguard water"

Ardith Wal'petko We'dalx Walkem, Lifeblood of the Land: Aboriginal Peoples' Water Rights in British Columbia (2004)

In doing research for this acknowledgement, SPEC learned that to local First Nations peoples, water plays a crucial role in many creation stories, produces valued food like fish and shellfish, and is used for healing and for ceremonies. It is our hope that this document will help farmers and landowners use water responsibly.

This manual was produced on unceded Coast Salish territories, and the case stories were developed in collaboration with farmers living and working on the unceded territories of the xʷməθkʷəy̓əm, Stz'uminus, Kwantlen, S'ólh Téméxw (Stó:lō), sc̓əwaθenaɁɬ təməxʷ (Tsawwassen), Katzie, W̲SÁNEĆ and Semiahmoo peoples.

Young Agrarians recognizes Indigenous title to all lands in Canada. It is our responsibility to care for and respect the land that we live on and depend upon for water, food and shelter. In a time of climate change, we must all do our part to nurture resilient food systems (local, ecological and equitably produced) choosing with our dollars, values and hands to grow and consume foods that are healthy for us and future generations.

# IMPORTANT NOTICE

The material presented in this publication has been prepared in accordance with generally recognized engineering and agricultural principles and practices in the province of British Columbia, and is for general information only. This information should not be used without first seeking competent advice with respect to its suitability for any general or specific application.

The content in this publication is not intended to be used as a standard for Young Agrarians or the Society Promoting Environmental Conservation, and is not intended for use as a reference in legal documents. No reference made in this publication to any specific method, product, process or service constitutes or implies an endorsement, recommendation, or warranty thereof by Young Agrarians or the Society Promoting Environmental Conservation.

Young Agrarians nor the Society Promoting Environmental Conservation makes no representation or warranty of any kind, whether expressed or implied, concerning the accuracy, product, or process discussed in this publication and assumes no liability. Under no circumstances will Young Agrarians or the Society Promoting Environmental Conservation be liable to any person or business entity for any direct, indirect, special, incidental, consequential, or other damages based on any use of this publication, including, without limitation, any lost profits, business interruption, or loss of programs or information.

# CREATED BY

**LEAD TECHNICAL RESEARCHERS & WRITERS**
Yuko Suda, P. Eng. and Mike Paget, P. Eng.

**PROJECT COORDINATOR**
Olga Lansdorp

**COLLABORATORS**
Young Agrarians, Society Promoting Environmental Conservation, Tsawwassen Farm School, Myles Lamont, Front Yard Flower Co., Karly Pinch, and Lionel Wessell

**CONTRIBUTING WRITERS & EDITORS**
Art Bomke
Sara Dent
Conley Keyes
Olga Lansdorp
Kate Menzies
Tara Moreau
Amy Sigsworth
Darcy Smith

**PHOTOGRAPHY**
Olga Lansdorp, Sara Dent, Sheila Sund, Darcy Smith, Rose Dykstra

**COVER PHOTO**
Sheila Sund

**FOCUS**
Case stories and other content focus on the Metro Vancouver region.

**FUNDERS**
Vancity, Vancouver Foundation

# ACKNOWLEDGEMENTS

Thank you to all of the participating farmers for sharing their stories and to our collaborators for capturing them, as well as the organizations and funders who make this work possible. Thank you to Yuko Suda and Mike Paget for their expertise, as well as Olga Lansdorp, Sara Dent and Darcy Smith for guiding this project. Special thanks to Art Bomke for his contributions on ecological farm design.

# YOUNG AGRARIANS

Young Agrarians is a farmer2farmer resource network for new and young farmers in Canada. YA's Grow-a-Farmer strategy engages new, young and potential farmers online, brings them together to network and learn together on and off farms year-round, and when ready to start farms, supports them to access land, as well as receive business and production mentorship from a seasoned farmer.

The long-term goal of YA is to increase the number of viable, new and ecological farm businesses in Canada. Since we started January 2012, YA has grown across the country coast to coast through a grassroots network of land and soil stewards growing local food systems. The network is made up of a diverse array of people: rural and urban farmers, market gardeners, livestock-raisers, holistic managers, regenerative agriculture practitioners, permaculturists, seed savers, food activists, bee keepers, community gardeners, food and farm organizations, and more.

Visit youngagrarians.org to get involved!

# SPEC

The Society Promoting Environmental Conservations provides practical solutions for urban sustainability, primarily in the Metro Vancouver region of British Columbia. Founded in 1969, SPEC is a non-profit, charitable and volunteer-driven organization that works at the local and grassroots level. SPEC collaborates with community members and organizations to strengthen and increase impact, works with integrity and an open mindset, and listens to create spaces for diverse perspectives. Through a positive and fun environment, SPEC strives to support, nurture, enable and educate community members for action. SPEC values clarity, focus and a resilient structure that can make our work more effective and productive. For more information please visit spec.bc.ca.

# CONTENTS

# HOW TO USE THIS GUIDE

New farmers face many challenges in start-up: from what to grow and how to market their products, to where to invest money, when to hire, and so on. Two key aspects that can make or break a farm early in its development are: reliable irrigation and good water drainage.

Reliable irrigation is important in British Columbia, where rainfall in the summer months can be scarce and sufficient water for crop irrigation is vital for good yields and quality crops. Without sufficient irrigation, a farmer must rely on natural rainfall, which can be unpredictable and at times insufficient for cropping needs. In addition, climate change is having an impact on rainfall events, potentially leading to more challenges in the future.

The need for good drainage can be a bit more obscure. A parcel of land may have a number of characteristics that can lead to drainage challenges, and those challenges can have an impact on farming, including shortened growing seasons, reduced yields, crop loss, and reduction in soil structure and quality.

When a landowner begins to consider the potential of their land for farming, it is important to objectively assess what the current capacity of the land is, the expected needs or demands that farming will require, and solutions to address the discrepancies between capacity and demand. Some farmland challenges can be overcome with management practices, such as crop selection and irrigation methods, while other challenges, such as drilling a new well or creating a new ditch system, require physical modifications and capital investments.

# THE PURPOSE OF THIS MANUAL

This manual is intended to support landowners and farmers to assess and improve drainage and irrigation for planning and implementation purposes. There are two key purposes to this manual.

The first purpose is to help you objectively decide, from an irrigation and drainage perspective, if your land can support a farming operation. The process is designed to be as objective as possible, so that you can:

- Determine if there are irrigation or drainage challenges on the land;
- Determine ways to overcome those challenges and the financial implications for each method;
- If the challenges cannot be overcome, whether they can be managed or mitigated by the farmer; and,
- If necessary, develop a plan to improve the drainage and irrigation systems so that farming is viable on the land.

The second purpose of this manual is to help established farmers determine if there are ways to improve irrigation and drainage on the land through shifts in farming practices. This may be prompted by several things, such as:

- Looking for ways to increase crop yields or quality;
- Considering how climate change may impact on-farm water over the short, medium and long term;

- Determining whether the land can support the scaling up of an operation; or,
- Assessing ways to improve efficiency on the farm and lower operating costs.

This manual focuses specifically on irrigation and drainage for farmland but will highlight other resources that may be useful to you along the way as you develop your farm plan.

# WHO IS THIS MANUAL FOR?

The primary audiences of this manual are farmland owners and farmers. This manual is focused on farms in British Columbia, with a specific focus on farms in the Metro Vancouver and Fraser Valley area, although irrigation and drainage concepts are universal. This document primarily focuses on the following types of farm operations:

- Vegetable or flower production;
- Field crops (as compared to hydroponic, greenhouse, and other types of controlled environmental crops); and
- Small scale operations (< 20 acres of production).

# SCOPE AND ORGANIZATION

This document is organized into the following chapters:

**Section 1: The Ecology of Agricultural Water Management** - This section introduces concepts of watershed management and ecological principles.

**Section 2: Assessing Irrigation** – This section focuses on how to calculate existing water capacity, calculate expected demand, and determine if an improvement to the water capacity is needed for the intended farming operation.

**Section 3: Assessing Drainage** – In this section, you will determine if the land has a drainage issue, and, if it does, how severe the issue is.

**Section 4: Bylaws, Regulations, and Resources** – This section will identify different bylaws and legislation related to irrigation and drainage on farmland. This chapter will also have a list of resources that you can use to help build your irrigation and drainage plan, as well as contacts for additional support.

**Section 5: Other Considerations** – This section looks at other things that may need to be considered when developing various plans. This chapter is laid out so that you can use it to look up specific topics.

# SECTION 1 - ECOLOGICAL WATER MANAGEMENT & FARMING

This section of the guide works to provide an overview of agroecological principles for water management in farming to protect ecosystems and grow food. Water management practices can be scaled down to the smallest of farms or scaled up to include whole watersheds and ecosystems. Ecological land use practices are of primary importance as we move into a future where climate adaptation and resource conservation are essential.

When landowners and prospective farmers are working out lease details and farm planning, water should be considered at the beginning of the process. The costs of improving drainage and irrigation can be high, and in some cases are constrained by upstream and downstream watershed considerations. In all planning processes, it is essential to do a cost benefit analysis, before deciding on which pathway to take for water management.

Below are strategies that may be applicable on the land to support a farm to leverage on-site water resources and benefit soil and the surrounding ecologies. New farms have the opportunity to 'plant' the water first, using ecological water management principles to grow productive food systems. This requires observation of the land, planning and design strategies, along with garnering local expertise to ensure that these potential solutions work best in your specific farming context. Many of the strategies outlined in this section are explored in more detail throughout this guide.

**Watershed Planning**

To increase water use efficiency on farm, integrated watershed planning works to project future water demand, water conservation, water storage, wetland water retention, and groundwater recharge. Impermeable surfaces and reduced soil water infiltration and retention are attributed to land use practices that include urbanization, logging, and agricultural activities. These activities more often than not challenge soils and aquatic ecosystems due to decreased watershed infiltration, and depending on the time of year either flooding or reduced stream flow. While individual farms rarely occupy entire watersheds, they have an effect on upstream land use, as well as influence downstream water quality and quantity. The best planning approaches involve prevention of land uses that jeopardize watersheds, and maintain watershed functionality and riparian areas. Remediation in many contexts, is often needed to restore watershed function.

**Soils**

Soil is designed to store water and nutrients and provide habitat for life. When soils are left intact they provide the most essential of functions within an ecosystem: acting as a sponge that allows water to infiltrate the landscape and be stored, capturing and recycling nutrients, and enabling plant root systems to thrive. When soils are degraded through poor management, they become less able to provide these key functions. Managing a farm, soil management strategies are key to the long-term health of the farm and its ability to use water well.

Soil health can be maintained by creating a management strategy for nutrient and disease mitigation, adding organic matter through compost, reducing foot and machine traffic on (wet) soils, minimizing tillage and, if necessary, subsoiling to ameliorate subsoil compaction. When drainage cannot be improved on farm through remediation activities, there are a few recommended options. Farmers can narrow the range of crops to those that can deal with on-site soil and water conditions and contribute to farm income, and consider shifting cultivation and other field operations away from wet soils such as tillage in the fall rather than spring when feasible. As well, a raised bed system for market gardening can increase the depth of soil above the water table.

**Crop Selection**

Choosing your crops wisely, based on the water potential of the landscape, is key. In B.C. we are often challenged by a dry growing season with too little precipitation to meet crop water demand at the hottest time of the year, especially for heat loving plant species. To increase a limited water supply, maximizing water use by crop is key. One approach is to focus some or all of the farm's crop rotation on plants that can make the most use of the moist, cool shoulder seasons, such as early planted vegetables like brassicas, alliums, and hardy greens. Winter cereals can offer choices for local grain production that then maximize use of precipitation.

**Mulches**

Another option for protecting soil moisture levels for crops is to avoid leaving soils bare through the use of mulches like straw, crop residues or manufactured paper for agricultural application. Mulches provide a protective barrier over the soil, that can improve weed control and reduce competition for water amongst plants. Mulches can also change other conditions for plants depending on the type of mulch and application that may or may not be desirable, such as reducing or increasing soil temperatures, and harbouring pests. Mulches can also be living, including cover crops (such as vetch, rye grass, clover, etc.) that benefit the soil in the shoulder seasons, keeping it covered and decreasing run off of precious nutrients. Pick your mulch strategy wisely!

**Drip Irrigation**

Drip irrigation was developed for agriculture where water resources are scarce, to ensure that water gets where it is needed most, and in the right quantities. Drip watering systems reduce evapotranspiration from the soil, and require on-going management and maintenance. Having a good management regime to maintain a drip system is necessary as hoses often require maintenance for debris, winter storage, and replacement parts as required.

**Permaculture**

Permaculture, coined by Bill Mollison, is an ecological design tool kit and land use philosophy that applies how Nature 'gardens' to grow resilient and productive food systems. Through observation of the land, and application of ecosystem principles, water management is considered a key element to creating a regenerative farm system. Aquatic systems are optimized to sustain their ecosystem service function, and improve and maintain ground water retention. While this type of system can take more work in advance, it can save precious labour hours down the road, while leveraging water resources when limited. Permaculture uses capture and store strategies to maximize on-site water resources.

**Swales**

Swales are ditches on contour used to capture water moving through the landscape, and increase soil infiltration, such as for perennial systems of orchards and vines. Swales can work at even a 1% incline in the landscape and do not require significant slope to be leveraged to direct water into root zones. In the same way we can pat down soils surrounding a new plant so surrounding water can infiltrate downwards to feed the root zone, swaling works across the landscape to capture, store and get water to where it is needed. Swales can happen at a small scale and much larger scale, referred to as earth works, depending on your landscape. There are dozens of resources online for learning how to build swales; on YouTube, search 'building swales on contour'.

**Ponds**

In a permaculture system, ponds are leveraged as catchments where possible above food production areas to allow water to be passively fed into the landscape through swales, ditches, and other water catchment strategies. A pond system must take into consideration the landscape and its contours, along with recharge rates and the type of soils on site. Permaculture uses a technique called gleying, which uses clay to seal the pond bottom for water retention. Plastic liners are also an option. Within a pond system, ecosystem functions are essential to keeping the water oxygenated and preventing build up of anaerobic activity. Permaculture focuses on creating a habitat for species diversity to allow for nature to regulate and maintain oxygen levels in the water. Look up permaculture and ponds to learn more.

**Keyline**

Keyline Design, developed by farmer and engineer P.A. Yeomans, was conceptualized to revitalize degraded grazing lands. Keyline looks for the 'keypoint' in the landscape where water concentrates, and then creates infiltration corridors for water to infiltrate into soils. This has been documented to build soil over time. In a keyline system, water run-off is reduced, and ground water retention is improved. Keyline design is more commonly associated with dryland conditions and usage of this methodology has increased throughout the world as the concept gets more traction. It is important to ensure that with any type of water management technique, that the time and energy put in are right for your farm project. For more information on keyline, and its use on the West Coast of British Columbia, check out Hatchet & Seed who have managed a number of keyline demonstration projects: hatchetnseed.ca/project/keyline-water-management-field-research-education-in-the-capital-region.

**Manufactured Water Catchment Systems**

Many farms invest in manufactured above ground water catchment systems for the part of the season where plants are thirsty and rainfall and available water resources are low or expensive. Investing in a water catchment system can provide a solution, when water is only needed for a window of time. These systems can be fed by rainwater catchment off of roofs (barn, house, etc.) or through other available waterways at the wet time of year, and stored for later use. They can then feed drip water systems or recharge swale and pond systems as needed. Depending on water potability requirements, these systems must also be kept clean.

**Environmental Farm Plan (EFP)**

For farms looking for resources to reduce the environmental impacts and increase ecosystem health, check out this government funded program in B.C. This is a voluntary system for devising farm specific plans for sustainable farming that also protects surrounding terrestrial and aquatic environments. The EFP Reference Guide identifies the scope of issues included and sets the stage for farmers to get in touch with a local EFP Advisor to then map out a pathway for remediation to reduce harmful agricultural practices. EFP's can help with water for irrigation use and farm drainage. To learn more about whether this program is a fit for you, visit: ardcorp.ca/programs/environmental-farm-plan

# SECTION 2 - ASSESSING IRRIGATION

Irrigation is an essential part of crop production in areas with water shortage. During the summer months in British Columbia, especially in July and August, there is not enough rainfall to irrigate many crops and additional water may be needed for farming. Roughly speaking, crops need an average of 5-10 mm water per day during the summer months to thrive.[1] That equates to 150-300 mm per month. In the Metro Vancouver and Fraser Valley region, that water requirement is not met by rainfall alone as early as April (see Figure 1), so irrigation may be required from April to October to compensate for the lack of rainfall. Irrigation water is also needed for crops that do not benefit from rainfall, such as greenhouse or other types of covered growing area.

When looking at land and the proposed farming activity, it is important to understand the existing water capacity on the land and the current or proposed farming activities, and to identify if there is a shortage in the water supply to support the farming activity. If there is a shortage, then ways to increase that capacity need to be found.

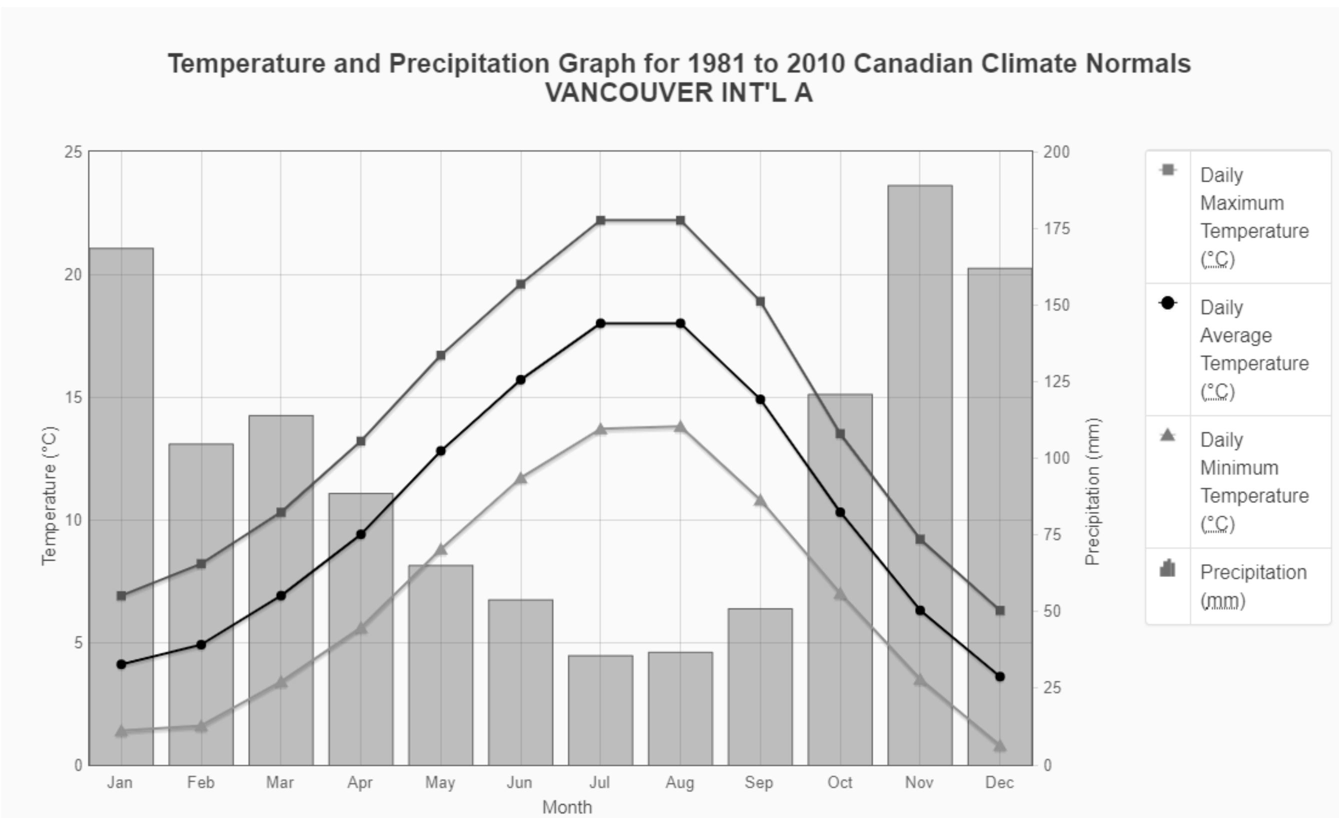



Figure 1: Typical Rainfall and Temperatures in Vancouver (Source: Environment Canada).

1 This is dependent on the location and crop type, and therefore further analysis is required to confirm specific water requirements.

The following are the steps you will follow in this chapter:

| Step 1: | | Step 2: | | Step 3: | | Step 4: |
|---|---|---|---|---|---|---|
| Identify available water source and flow rates | → | Identify water requirements for farming | → | Determine if there is a capacity issue | → | Identify feasible solutions to increase capactiy |

# 2.1 - DETERMINING EXISTING WATER CAPACITY

The following lists some of the sources of water that might be available on your land:

- Underground Water (typically accessed by a well pump);
- Municipal Connection;
- Surface Water (includes lakes, rivers, ditches, etc.); and
- Rainwater Collection and Storage.

When assessing the existing water capacity of the land, there are two factors that must be considered. The first is peak flow rate, or capacity, of the water source, and the second is total available volume over a growing season.[2]

## Peak Flow Rate

Peak flow rate of the water is the maximum rate at which the water can be discharged from a connection point (e.g. faucet or water hydrant). There are many ways that this can be calculated depending on the water source, conveyance method (e.g. using pumps), and the configuration of the system.

The simplest way is to physically measure the peak flow rate from the system. In the context of irrigation, the measurement should be taken at the point where irrigation water will be sourced. That is, if the field is going to be located away from or at a different elevation than, say, the house, then the rate of water coming out of the hydrant at the field should be measured, not at the house. The simplest way to measure the peak flow rate is to take a vessel of known volume and measure how long it takes to fill up, using the following equation:

$$\textbf{\textit{Peak Flow Rate}} = \frac{\textbf{\textit{Volume}}}{\textbf{\textit{Time}}}$$

***Where:***

***Volume = the total volume that was discharged during the test.***

***Time = the time over which the test ran.***

Typically flow rates are reported in:

- L/s – Litres Per Second
- m3/s – Cubic Meters per Second

2 Typically, between March and October in the Metro Vancouver / Fraser Valley region of British Columbia, though this varies throughout the province.

- US GPM – US Gallons per Minute
- Imp. GPM – Imperial Gallons per Minutes

It should be noted that US Gallons (3.78 L) and Imperial Gallons (4.55 L) are different and should be confirmed when reviewing literature or calculating flow rates.

It should also be noted that as water travels further from the source, flow rates will drop because of the energy that is lost in the piping system (and in some cases, because of minor leaks in the system). The final peak flow rate will be lower depending on how the irrigation system is set up. For the purpose of this exercise, it would be a good idea to reduce the Peak Flow Rate available by 20% to account for these losses (though in some cases it can be much more).

There are many other innovative ways to measure the peak flow rate that are not discussed in this manual. If the method outlined in this manual is not sufficient, then a professional should be consulted to assist with flow rate testing.

The considerations outlined in Table 1 should be reviewed for each water source.

## Table 1. Farmland Water Sources

| SOURCE | IMPACT | CONSIDERATIONS FOR TESTING |
|---|---|---|
| **Well** | **Well Pump Operation**<br><br>A well is typically operated with a combination of a well pump and a hydropneumatic tank (known commonly as a bladder tank). A well pump and a hydropneumatic system operate together to maintain a constant pressure in the water system (so that the system pressure doesn't spike every time a faucet is turned on or the pump starts, for example).<br><br>A hydropneumatic tank has a built-in bladder that moves up and down, trying to maintain pressure in the system as the water is used up in the tank. Once the water is used up in the tank and the pressure in the system drops, the well pump turns on to refill the tank.<br><br>When the pump is off, and the tank is full, the water system is under the highest amount of pressure, so the flow rates coming out of faucets will be high. Conversely, if the tank is nearly empty, the pressure will be low, and therefore the flow rates will be low. The flow rate under high pressure is not sustainable, and therefore it is not accurate to test the peak flow rate under this condition.<br><br>When the well pump turns on, it will pressurize the system, pushing water through the pipes and once again filling the tank full | The best way to assess peak flow rate for a well pump is to measure the average flow rate over an entire pump cycle. That is, from when the well pump is off, and the hydropneumatic tank is full, through the emptying of the tank until the well pump turns on to refill the tank, and then finally turns off again. The tester may observe that the water pressure in the system changes over the course of the test.<br><br>One thing to keep in mind is that if the well pump is pumping at the exact same rate as the water coming out of the system (i.e. a steady state is reached), then the well pump may never turn off, and the peak flow rate will be the same as the well pump rate. |

| SOURCE | IMPACT | CONSIDERATIONS FOR TESTING |
|---|---|---|
| **Well cont'd.** | **Time of Year**<br><br>The groundwater table of many aquifers (the water stored in the ground) can vary with the season. Typically, the groundwater table is high in the winter months as it is replenished with rainfall and snow melt, but is lower in the drier summer months. This is especially true if many users (i.e. wells) are connected to the same aquifer and are depleting the aquifer over the season. As the groundwater table lowers, the pumps must work harder to get more water out of the ground, and therefore the flow rates will drop. | The tester should note the time of year that the test is being conducted, and factor in the changes to the flow rate that will occur over the months, especially in the summer when the most water is required. |
| | **Future Changes**<br><br>The peak flow rate may change in the future, due to a number of factors:<br>• Additional wells connect to the same aquifer that may draw more water out of the ground.<br>• Climate change may cause the water table to lower.<br>• During water shortages, the government may restrict or prioritize groundwater use. | The tester should be aware of potential future conditions, and if necessary, factor in these considerations. |
| **Municipal Connec-tion** | **Time of Day**<br><br>Generally speaking, water pressures are highest during night-time, as other users are not using the water.<br><br>In a municipal system, typically the maximum water demand occurs between 8 AM and 10 AM and between 4 PM and 9 PM, and so water pressure from the mains may be lower during these periods. | The tester should be aware of the time of day that the test is being conducted. It is beneficial to test the peak flow rate at both mid-day and at night-time, in case the flow rates are substantially different. |
| | **Pressure Reducing Valves**<br><br>Pressure reducing valves are typically installed at a house connection for a number of reasons. Primarily it is to protect the house from pressure surges that may occur from the municipal system. But this can serve to reduce the flow capacity for the house, especially at high flow rates. | The tester should be aware if a pressure reducing valve is located in the system, and whether it can have an impact on the flow rates. |
| **Surface Water** | **Water Level**<br><br>Typically, water from surface sources, such as ditches, lakes, creeks, etc, is drawn using a pump and connected to the irrigation system. Water is 'turned on and off' using the pump, rather than opening and closing a valve (like a household faucet or a pressurized water system), unless a hydropneumatic tank is installed (see Well section above). The water level of the source is then important, as the lower the water level, the more the pump must work to pump the water and lower the flow rates. | The tester should be aware of how much variation in the water level exists over the season, as it will impact the peak flow rate. |

| SOURCE | IMPACT | CONSIDERATIONS FOR TESTING |
| --- | --- | --- |
| **Surface Water cont'd.** | **Water Use Licence**<br><br>Though not directly related to the available peak flow rate, when pulling water from ditches, lakes and other surface sources, a water use licence is required (see Chapter 4 for more information). A water use licence typically limits the maximum rate of water that can be extracted from the body of water. | The tester should be aware of the water use licences that are in place and the impact it may have on the peak flow rates available for use. |
| | **Time of Year**<br><br>The surface water availability can vary with the season. For example, typically ditches are full during the winter and spring months, however as water in the ditch system is depleted and is not replenished with rainwater, there will be less and less water available from the ditch system. This is especially true if many users are connected to the same surface water system and are depleting the surface water source over the season. Water may become completely unavailable during certain times of the year (especially in summer months). | The tester should be aware of the time of year that the test is being conducted, and factor in the changes to the flow rate that will occur over the months, especially in the summer when the most water is required. |
| | **Future Changes**<br><br>The peak flow rate may change in the future, due to a number of factors:<br>• Additional users connect to the same surface water system.<br>• Climate change may reduce the amount of water replenishing the surface water source, especially in the summer months.<br>• During water shortages, the government may restrict or prioritize surface water use | The tester should be aware of these future conditions, and if necessary, factor in these considerations. |
| **Rainwater Collection and Storage** | **Water Level**<br><br>Typically, water stored in some type of vessel (e.g. tank or on-farm pond) is either moved by gravity or by pump. In either case, the water level in the tank will have an impact on flow rates. When the water level is high, then higher flow rates are expected, when the water level is low, then lower flow rates are expected. | The tester should note the water level in the storage vessel when conducting the test. If possible, the test should be conducted when the tank is full and again when the tank is near empty, so that a range of available flow rates are obtained. |

# EXAMPLE 1: CALCULATING FLOW RATE

Mary's property is located in Surrey, B.C. on five acres of land. Her property has two sources of water: water from a drainage ditch for which her parents had obtained a water use permit from the 70's that is still valid, and a drinking water well that is 100 m deep.

The water from the drainage ditch is managed under the following water licence restrictions:

- Purpose of the water is to be used as irrigation;
- Maximum quantity of water which may be diverted is 25 acre feet per annum;
- No maximum withdrawal rate is specified; and
- Period of the year during which the water may be used is April 1 to September 30.

The irrigation shed that her parents used is still there and the pump in it still works, but she doesn't use it right now.

The well that she uses primarily for drinking water is located a few metres from her house and has a well pump installed. The pump pumps into a shed that has a hydropneumatic tank and a switch that turns the pump on and off, based on the pressure in the system. When the pressure is at 60 psi, the pump turns on, and it turns off at 75 psi.

**Calculation**

Based on the above information, Mary calculated two peak flow rates: one for her well and the other for the ditch.

**Well:** Mary calculated the peak flow rate for the well using a 120 L plastic bin she uses to store things in her garage. She took the following steps:

1. She first opened the garden faucet by her house. She noticed that the water came gushing out initially, but the flow started to drop over time. Then the flow rate suddenly went up, so she knew that her well pump had turned on.
2. She closed the garden faucet, went to the well shed and looked at the pressure gauge (since the well motor is down deep in the ground, there is no way to tell when the pump turns off). Once the pressure gauge stopped moving, at 75 psi in her case, she knew that her well had stopped pumping and the entire system was full. She was now ready to test her flow rates.
3. She opened the garden faucet and started her timer. As her bin started to fill up with water she noticed, like before, the water rates starting to drop and then pick up again (when the well started pumping again).
4. Because she couldn't tell when the well turned off, she let the water run through this cycle of the well turning on and off twice, so that she was confident she knew roughly when the well turned off (she could tell when it turned on, but not off, by looking at the water flow). She stopped the timer at roughly the point she felt that she had gone through two full well cycles (from when the well pump was off, to the pump being on, to then turning off again).

She found that she was able to fill her 120 L plastic bin 3 times over the course of 30 minutes.

Based on this she calculated:

$$\textbf{Peak Flow Rate} = \frac{120\ L \times 3}{30\ minutes}$$

$$= 12\ L/minute\ or\ 0.2\ L/s$$

Mary's garden faucet's peak discharge rate was **0.2 L/s** on average.

Mary also knew from experience that in the summer months, there are times when she would use a lot of water (e.g. filling her pool) and noticed that it seemed like the pump couldn't keep the system pressurized. She knew that this happened when the groundwater level was low and the pump would barely keep up with her water use. She estimated that her peak flow rate dropped by 20% when this happened.

**Ditch:** Mary now had to calculate the peak flow rate for her ditch pump.

Measuring the ditch pump's peak water flow was much harder than her house well, because this pump was meant to irrigate large areas, so it would shoot water at high velocities out of the pipe. She couldn't just stick a bucket under it like her house faucet. She took the following steps:

1. Mary decided to talk to her local pump supplier to see if there was an easy way to figure out the flow rate, since the pump make and model information wasn't available on the pump.
2. After discussing with them, she decided that the cheapest and simplest way was to get the lay-flat hose that her parents had used back in the day to get the water from the pump to the farthest field, and time how long the water took to go from the pump house to the end of the hose.
3. She laid the hose on the ground and connected it to the pump. The hose was 200 m long and 100 mm in diameter.
4. With the help of her neighbor and a cell phone, she started the test. She turned on the pump and started the timer. Her neighbor, on the other end of the hose with a cell phone, told her when the water came out of the hose.

The time it took the water to get from one end to the other was **120 seconds**. Based on this information she calculated the following

$$\textbf{Velocity of the Water} = \frac{Total\ Distance}{Time}$$

$$= \frac{200\ m}{120\ seconds}$$

$$= 1.67\ m/s$$

$$\textbf{Peak Flow Rate} = Velocity\ of\ the\ Water \times Area\ of\ the\ Hose$$

$$= 1.67\ m/s \times \pi r^2$$

$$= 1.67\ m/s \times 3.14 \times (0.05\ m)^2$$

$$= 0.013\ m^3/s$$

$$= 13\ L/s$$

Mary knew that this math was approximate, since there were so many variables that could affect the test results (e.g. ditch water level, location of field, size of piping, etc), so she decided to reduce the peak available flow by 50% to account for these variations.

**Solution**

Based on the simple test she did, she concluded that:

- Her peak water flow from her well source was 0.2 L/s, which she lowered to 0.15 L/s to account for summer conditions.
- Her peak water flow from the ditch pump was 13 L/s, which she lowered to 6.5 L/s to account for the variations that would happen over a growing season, the irrigation style, rainfall, etc.

# Total Volume Available

The total volume of water available over a season on site is important for sources that diminish over time or are limited in the total volume available. In the case of irrigation, the total volume does not necessarily mean the absolute total volume in a storage vessel, but rather the total volume available over a growing season. In our case, this will be for:

- Sources that require storage, including tanks and on-farm ponds;
- Sources that have such low flow rates that water needs to be stored over hours or days, and then used for irrigation with a pump; and
- Sources that are under a water use licence where the total volume that can be removed is specified.

The last case is simple, as it will be specified in the permit; however, calculating the total volume available can be complicated especially for sources that replenish over time (e.g. pond) or depleted with non-irrigation activities (e.g. evaporation).

**Calculation**

The calculation of total volume is the sum of the initial volume available at the start of a season, and the additional volume that is added over the season, as follows:

***Total Volume = Initial Volume + Additional Volume***

The initial volume is relatively simple to calculate. A tank is relatively easy to measure and calculate the volume, however ponds can be harder. A simple method is to measure the total surface area though tools such as Google Maps, and calculate volume assuming a cone using the deepest depth, with the following equation:

$$V = A\frac{d}{3}$$

Where:

***V = Total Volume***

***A = Surface Area of Pond***

***d = maximum depth of pond***

The additional volume added to the storage over the season is more difficult to calculate, depending on the source. For discussion we will assume two sources: a constant flow from a municipal tap/well, or from rainfall.

For a constant flow, then the calculation for the volume added to a storage vessel is simply the flow rate multiplied by the duration over which it contributes to the irrigation system.

***Total Volume from Constant Flow = Flow rate x Time***

For rainfall-based contribution, the following calculation is used:

***Total Volume from Rain = Rainfall × Contributing Area × Retention Factor***

Where:

***Rainfall = Total rainfall, in mm, that fell***

***Contributing Area = the total area that feeds into the pond***

***Retention Factor = total fraction of the rainfall that fell that is collected in the pond***

## EXAMPLE 2: CALCULATING TOTAL AVAILABLE WATER VOLUME

Navi's property has a pond at the bottom of the property that can be used for irrigation. The pond was constructed by the previous owner as a water feature and is lined with an HDPE liner on the bottom. The pond is large and in relatively good shape. During the winter, the pond is completely full of water. It is connected to the local ditch, where excess water is discharged. In the summer months the water level drops to about 50% of the depth of the pond. Since the land slopes in that direction and all the ditches are connected to the pond, when it rains, the pond water level rises up again.

**Calculation**

Based on the above information Navi calculated the total available water volume from the pond using the following steps:

1. First Navi needed to calculate the total volume of water the pond can hold. He used Google Earth and the Area tool to calculate the surface area of the pond. The surface area was 100 $m^2$. He knew from past experience the pond was 2 m deep at the deepest point, so the initial total volume available was:

$$\textbf{Total Initial Volume} = \textbf{Surface Area} \times \frac{\textbf{Maximum Depth}}{3}$$

$$= 100\ m^2 \times \frac{2m}{3}$$

$$= 66\ m^3$$

2. Navi now need to figure out the additional volume that contributed to the pond over the growing season. He knew that once the rain stopped in May, very little water overflowed into the ditch, and the water level would gradually begin to lower from evaporation.

Over the summer months he observed the water level during a few rainstorms and noted the following:

| DATE | TOTAL RAINFALL (mm) | WATER LEVEL BEFORE RAIN | WATER LEVEL AFTER RAIN |
|---|---|---|---|
| June 3 | 15 mm | 1.85 m | 1.95 m |
| June 15 | 20 mm | 1.90 m | 1.96 m |
| July 5 | 5 mm | 1.20 m | 1.20 m |
| September 15 | 10 mm | 0.9 m | 1.10 m |

3. Using his recorded data and an online calculator, he calculated that every time it rained, he got about 1 m3 of water for every 1 mm of rainfall, but only rainfall above 5 mm would increase his pond water level.
4. Using the precipitation information from Environment Canada for the last two years in his area, between the months of May and September, he calculated how much water he expected would be added to the pond each time it rained. He made sure to take only rainfall events that had more than 5 mm of rain and removed 5 mm from the rainfall depth for each calculation.
5. Based on this, he calculated the following:

| YEAR | DATE | TOTAL RAINFALL (mm) | TOTAL VOLUME ($m^3$) |
|---|---|---|---|
| Year 1 | May 22 | 20 | 15 |
| | June 1 | 15 | 10 |
| | June 22 | 5 | 0 |
| | July 2 | 5 | 0 |
| | August 23 | 10 | 5 |
| | September 10 | 30 | 25 |
| **Total Volume for Year 1** | | | 55 |

| YEAR | DATE | TOTAL RAINFALL (mm) | TOTAL VOLUME ($m^3$) |
|---|---|---|---|
| Year 2 | May 15 | 15 | 10 |
| | June 3 | 15 | 10 |
| | June 15 | 20 | 15 |
| | July 5 | 5 | 0 |
| | August 6 | 2 | 0 |
| | September 15 | 10 | 5 |
| **Total Volume for Year 2** | | | 40 |

6. Navi knew that the storms at the beginning of the growing season probably wouldn't count, because the pond would just overflow, so he decided to remove the storm volumes that happened in May for each year. He also knew that in summer months the water evaporated about 2 cm a week, especially in July and August, so removed that volume as well (which he calculated to be about 2 m3).

Navi then calculated the additional volume that was available during the season was 38 m3 for year 1 and 28 m3 for year 2.

**Solution**

Based on the calculation, Navi decided that in May the initial volume of the pond was about 66 $m^3$, and that about 28 to 38 $m^2$ of additional water was available from rainfall during a typical growing season. With this information, he was able to estimate that about 100 $m^3$ of water was available, on average, over the growing season.

# 2.2 - IRRIGATION BASICS

In order to determine a farmer's water demand, some understanding of irrigation as it applies to crop production is necessary.

Evapotranspiration is the driver of irrigation needs for crops. Evapotranspiration is a combination of the evaporation of moisture from the soil and plant surfaces, and the water transpired (given off as vapour) through the plant itself. For optimum crop yields, the irrigation rate then must match or exceed the evapotranspiration rate occurring in the field.

Irrigation is achieved through natural precipitation and soil moisture, but when those two are insufficient to keep the plant healthy, additional water is needed.

How a field is irrigated can impact the specific irrigation requirements for a given crop. Table 2 outlines the common styles of irrigation systems available in B.C.:

## Table 2: Irrigation Systems Commonly Available in B.C.

| SYSTEM | DESCRIPTION | CHARACTERISTICS |
|---|---|---|
| Drip/Trickle | Drip/Trickle irrigation is when water is directed into hoses punctured with small holes at regular intervals in order to 'drip' water directly into the root zone of the plant. | • Low pressure system<br>• Efficient<br>• Not suitable for all cropping systems<br>• Drip hose required for each and every row of crops<br>• Limits to the distance a drip hose/ tape can be used (100 – 200 feet)<br>• Long irrigation times required<br>• Hose needs to be immediately beside the crop<br>• Takes a lot of time and effort to set up and break down each season. |
| Sprinkler | Sprinklers spray water onto the crops from above using some type of sprayer. | • Uniform application is required for proper water management<br>• Water is lost due to evaporation and non-targeted application (e.g. in walkways)<br>• Relatively simple to set up<br>• Large area of application<br>• Indeterminate in its application (e.g. walkways). |
| Gun | A gun system sprays water onto crops from above, but operates at much higher flows and pressures than a regular sprinkler system. | • Higher evaporation losses than a sprinkler system.<br>• Less efficient than sprinkler and drip system<br>• Able to irrigate a significant distance.<br>• Shorter irrigation durations due to high flow rates. |

# 2.3 - PEAK IRRIGATION RATE AND PRESSURE REQUIREMENTS

Peak Irrigation Rate is the water rate required for an irrigation set up to work effectively. Pressure requirement is the water pressure that is necessary for the irrigation set up. For example, a gun system requires a high flow rate and pressure for operation (30-1200 gpm and 40-160 psi, per head), compared to a sprinkler system (2-8 gpm and 25-50 psi, per head) or a drip system (0.2-0.3 gpm per 100' of drip tape and 5-15 psi). The peak irrigation rate and pressure that is needed by an irrigation system for proper operation is usually provided in the literature for the irrigation system selected, and can be found on the supplier's website or from the supplier representative.

**Annual Crop Water Requirements**

The annual crop water requirement is the total volume of water required over a season for growing vegetables. You can find this requirement in the B.C. Irrigation Management Guide.[3]

3 https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/irrigation/irrigation-management-guide

The total water requirement is based on:

- Climate – in a sunny and hot climate, crops need more water than in cooler climates; and
- Crop Type –different crops, and even different varieties of the same crop, vary in their specific water requirements

**Determining Water Demand**

In this step you will calculate how much water is needed to effectively manage a farm on your parcel of land. The Province of British Columbia has made a comprehensive online water calculating tool (Figure 2), that allows landowners to assess the water requirements for different types of farming (both vegetable and livestock), specific to their land. Use the **B.C. Water Calculator** to determine water requirements for your farm site. Once you input the information, the website will provide information on the Peak Flow Rate required, and the Irrigation Water Demand (in annual and monthly volumes).

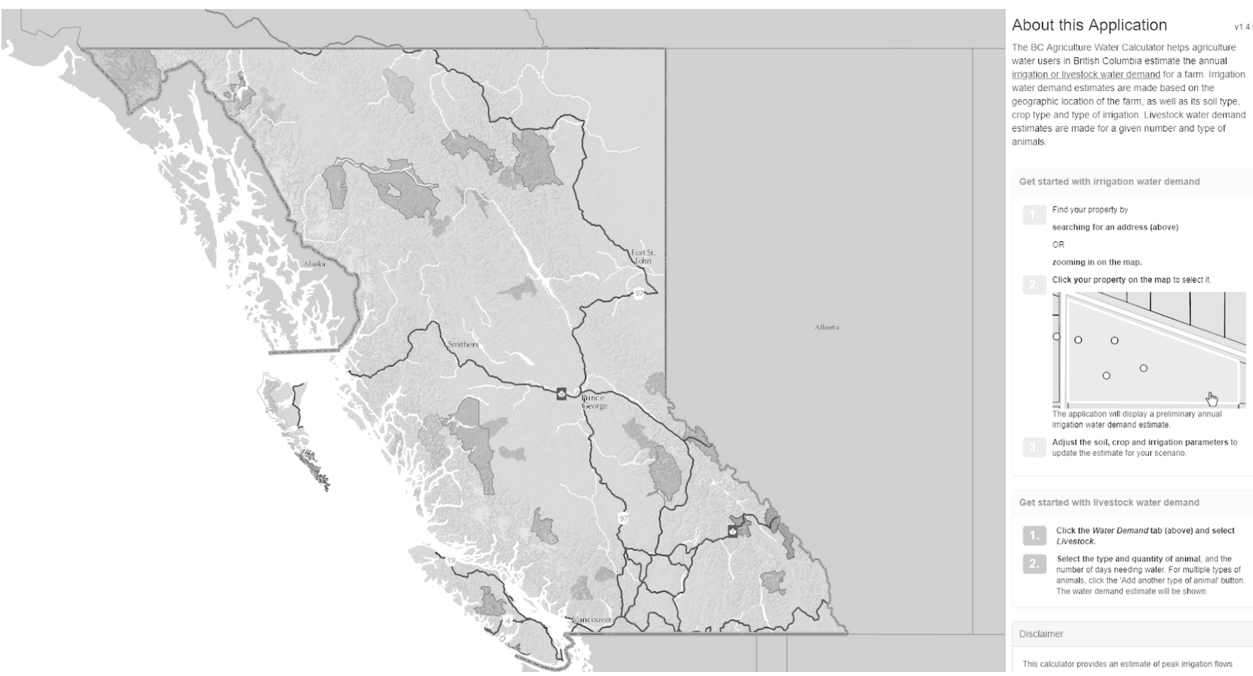



Figure 2. BC Agriculture Water Calculator

# 2.4 - DETERMINE IF THERE IS WATER SUPPLY SHORTAGE

Once you have calculated your water capacity in Chapter 2.1 (both peak flow rate and total available volume) and compared it to the water demands for your proposed cropping system in Chapter 2.3, you can determine if there may be a water supply shortage.

As a starting point, the following flow chart (Figure 3) will assist you in determining whether you have a shortage, a slight shortage or significant shortage.

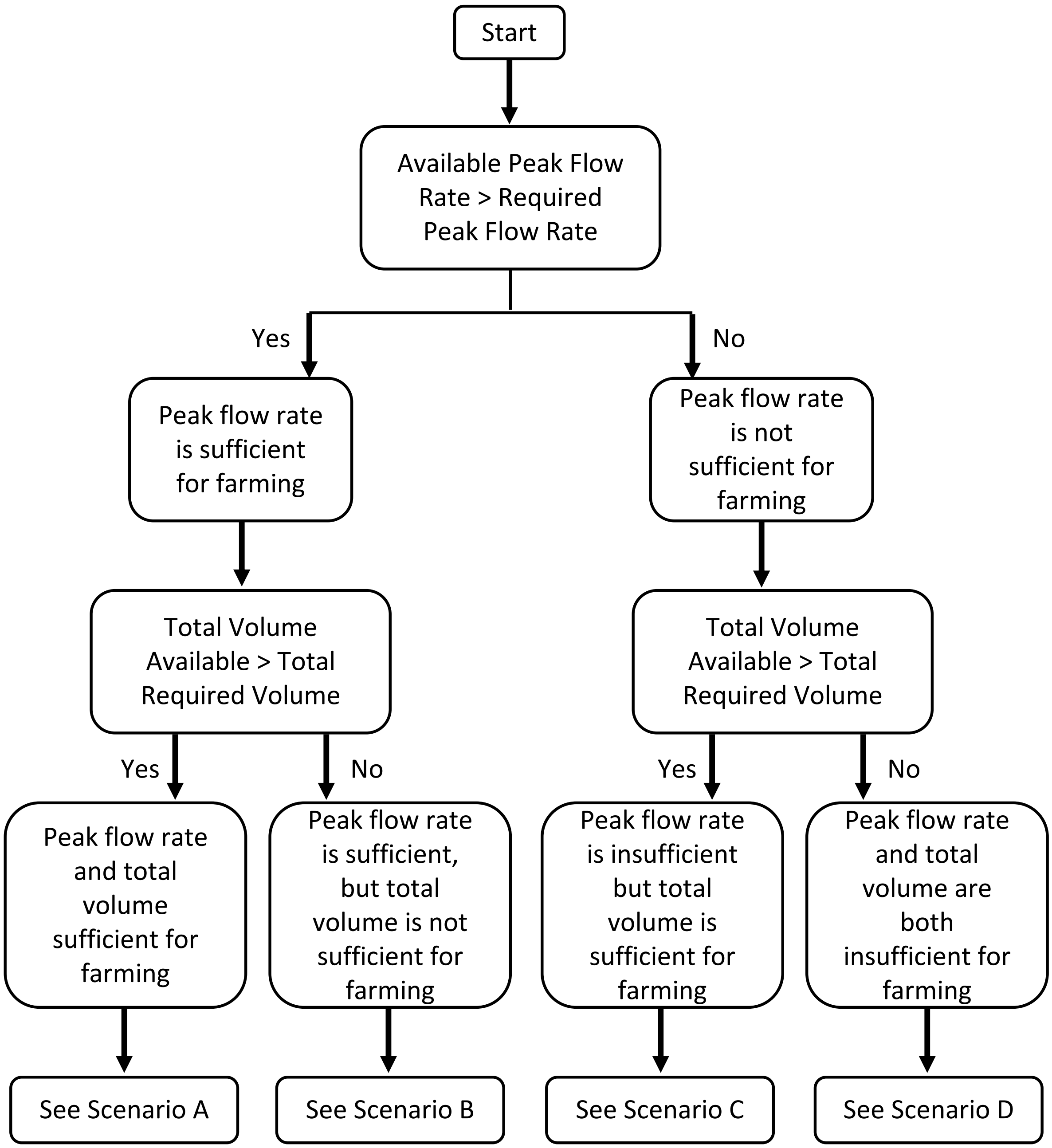



Figure 3: Flowchart to determine if there are potential water supply shortages on your farm.

From the flowchart, you should have come to one of four scenarios. Based on which scenario you have arrived at, different solutions are proposed to address potential shortcomings (if there are any). The proposed solutions are discussed further in Chapter 2.5.

**Scenario A - Sufficient water for a full growing season:**

In this scenario, you have enough peak water flow and total water volume over the growing season to meet the farming needs proposed on your property. No significant modifications are likely required on your property to meet the farming needs.

**Scenario B - Sufficient water but not enough for a full growing season :**

In this scenario you have enough peak water flow from your source, but not enough volume for the growing season. Typically, this occurs when you have a large enough pump to convey the flows, but not enough storage to store all the water that is needed over the course of a season. The following are a selection of solutions to this problem:

- Increase storage capacity.
- Increase additional volume of water into the storage system.
- Decrease water loss from the system.
- Decrease the total water requirement.

**Scenario C - Sufficient volume but low flow:**

In this scenario you have enough total volume of water for a growing season, but the peak flow rate is not sufficient to support the proposed irrigation method. Typically, this happens if the cultivation area is very large and the existing infrastructure is unable to support the selected irrigation method, or the flow rates from the fixture is very low. The following are a selection of solutions to this problem:

- Increase flow capacity.
- Increase size of or addition of a pumping system.
- Reduce peak demands.

**Scenario D - Not enough water and flow for a full season:**

In this scenario both the peak flow rate and the total water volume are insufficient for farming needs. This typically happens if there is not good access to water, such as the remoteness of the farm from water sources or inability to obtain water use permits for irrigation. In this case a combination of solutions likely needs to be reviewed, including:

- Increase storage capacity.
- Increase additional volume of water into the storage system.
- Increase or create on-site storage with a pumping system.
- Decrease water loss from the system.
- Decrease the total water requirement.
- Increase flow capacity.
- Reduce peak demands.

# 2.5 - SOLUTIONS TO ADDRESS WATER SUPPLY SHORTAGES

In the previous step, a number of solutions to address the water shortage was introduced. These were:

- Increase storage capacity on the farm;
- Increase additional volume of water into the storage system;
- Increase size or addition of a pump system;
- Decrease water losses from the system;
- Decrease the total water requirement;

- Increase flow capacity; and
- Reduce peak demands.

Each of the solutions will be introduced in this chapter. However, specific management practices to increase the volume of water available for irrigation or improve the on-farm water use efficiency should be grounded, as much as possible in sound landscape management. These principles may be found within agroecological systems such as keyline design and permaculture and can be applied to the extent that control can be exerted over the production unit and the watershed in which it is situated.

**Increase Storage Capacity on the Farm**

If there is a need to increase storage capacity of water on site, a few options are available, including:

- Increasing or adding a detention pond: Adding a detention pond can be as simple as digging a depression into the ground and directing surface runoff to it, or as complicated as lining it with an HDPE or clay liner. The following resource is recommended for further discussion on sizing a storage pond, the considerations, and case studies: bcagclimateaction.ca/wp/wp-content/media/FarmPractices-WaterStorage.pdf
- Adding water storage tanks: Water storage tanks can be brought in or constructed on the farm. Typically, these can be built from plastic, fibreglass reinforced plastic, concrete, wood or metal and come in a variety of shapes and sizes.

**Increase Additional Volume of Water into the Storage System**

Increasing the water that contributes to the storage system is another method to increase the total volume of water used for irrigation. The idea is to replace the water that was lost due to irrigation through other means. This may include:

- Rainwater collection: Rainwater collection is accomplished by directing rainwater to the storage system. Impermeable surfaces (e.g. the roof of a house or barn) are excellent options to redirect water; however, these options are limited in the contributing surface area (which can limit the total volume of water contributing to the system). Surface runoff from large areas (e.g. fields, driveways, etc) can be redirected to the storage system; however, significant losses are expected, from evaporation to ground infiltration.
- New or alternate low flow water source: New or alternate low flow water sources may include installing a low capacity well pump, and pumping water from other bodies of surface water.

**Increase Size or Addition of a Pumping System**

This method is generally used when the incoming flow is too low to support an irrigation system. For example, it may be that the well size is too small to be able to pump the peak flows that are necessary for the sprinkler system, or the municipal connection is too small for the required flows. In these cases, it is possible to allow the water to discharge over a long duration into a storage tank of some type (see previous discussions) and then pump the water from the storage tank into the water system using a larger pump.

### Decrease Water Loss from the System

Decreasing the water lost from the storage system is another option. This may include:

- Manage leaks in the system: Leaks in the system can be managed by assessing areas where leaks may occur (e.g. infiltration of water into the ground through the bottom of the pond) and sealing them.
- Reduce evaporative losses: Reducing evaporative losses is achieved by covering the storage (typically a pond in this case) to prevent evaporation.

### Decrease Total Water Requirement

Rather than increasing the total water requirements for the farm, the alternative is to decrease the water demands from the irrigation system. Decreasing the total water requirement is mostly accomplished by the farmer, rather than the landowner, through farm management practices. These may include:

- Efficient watering systems.
- Farming practices that reduce the requirements for water.

### Efficient Watering Systems

Wise use of existing water is mainly accomplished through mechanical means and does overlap to some extent with decreasing water loss from the system (from above). Examples of this include:

- Using drip irrigation system to target water directly at the root system. In some cases drip systems can be buried so that water is not lost due to evaporation at the surface of the soil.
- Irrigation during early morning hours gives the water time to infiltrate to the lower levels of the soil, before it is lost due to evaporation under the hot sun.
- Mulching, including wood chips, leaves, plastic, and paper mulches, can be used to keep the water in the ground so that it is not lost to evaporation.
- Using an irrigation timer to water on a schedule and for a set duration makes sure that the crops are not being over watered.
- Using a water meter to measure the exact volume of water used. Knowing this can lead to a better understanding of the ideal volume of water for certain crops.
- Using a soil moisture sensor to understand the water content in the soil. Using this scientific tool, combined with an understanding of the ideal moisture for certain crops, can lead to a better irrigation (and potentially higher yields) as crops are watered only when they need it.
- Irrigation systems which monitor soil moisture and turns on the irrigation system automatically, when the soil moisture content drops below a certain setpoint, is one of the most efficient watering methods.

### Farming Practices to Reduce Water Requirements

Alternative farming method to reduce crop water requirements in south coast B.C. include:

- Crop selection. Increased focus on crop species and varieties that make use of natural rainfall such as overwintering vegetables and grains that can be grown with no or minimal irrigation.
- Reduced tillage. Conventional farming often depends on many tillage operations, each of which increases evaporation from the soil. Minimizing the number of tillage operations

and shifting some of them to the fall may in some cases may also conserve water.
- Landscape design. Permaculture design may include windbreaks that can reduce wind speeds and crop moisture stress due to evapotranspiration.
- Soil health. Practices that conserve soil organic matter and protect soil structure such as reduced tillage, cover cropping, and mulching can improve infiltration and retention of rainfall and increase the soil's capacity to store available water for crops.

**Increase Flow Capacity**

Increasing flow capacity likely requires modifications to the water system on the property, or off the property (i.e. municipal side). These include:

- Larger pumps;
- Larger pipe diameter; and
- Reducing energy loss (e.g. larger pipe diameters, shorter pipe distances).

Before considering larger pumps, it would be prudent to determine what, within the existing irrigation/water system, is limiting the flow rates. The pump may be adequately sized, but the conveyance system (e.g. pipes, valves, filters) are too small, resulting in too much energy loss through these fixtures. As a guideline, 3-4 m/s is a reasonable maximum velocity for water flowing through a water system. After this point, the amount of energy lost can be significant, and the desired flow rate hard to achieve. Based on this guideline, the following is the maximum recommended flow rate for each pipe size.

# TABLE 3: MAXIMUM RECOMMENDED FLOW RATE

| PIPE SIZE | MAXIMUM RECOMMENDED FLOW RATE | |
|---|---|---|
| | USGPM | L/s |
| 1/2" | 7 | 0.5 |
| 3/4" | 17 | 1 |
| 1" | 30 | 2 |
| 2" | 117 | 7 |
| 3" | 260 | 17 |
| 4" | 470 | 30 |
| 6" | 1,000 | 70 |
| 8" | 1,800 | 120 |
| 10" | 3,000 | 185 |

If the size of the fixtures and pipes are not the limiting factor, then a larger pump should be considered. Pump selection can be complicated, as there are many types of pumps with very different performance ranges; consult the local pump supplier to correctly size the pump.

### Reduce Peak Demands

Reducing the peak demand required by the irrigation system is accomplished by modifying the farming practice including:

- More efficient irrigation system;
- Farming practices that reduce watering requirements; and
- Offsetting the irrigation to reduce the overall peak demand.

As with Decrease Total Water Requirement solution, this requires action from the farmer through changes to the farming practice. This may include dividing the farm into zones and irrigating smaller areas in sequence or selecting drought tolerant crops that require less water.

# 2.6 - ALTERNATE SOURCES OF WATER

The previous section discussed methods to 'push the limits' of the existing water sources to address water shortage. However, in some cases the water shortage is severe enough that an entirely new water source must be established. The following are typical sources of irrigation:

- Well;
- Surface drainage; and
- Municipal.

### Groundwater Wells

Currently wells in British Columbia for landowners fall under two categories:

- Wells for non-domestic purposes; and
- Wells for domestic purposes.

The Water Sustainability Act requires that wells for non-domestic purposes require a licence as of March 1, 2016.[4] The one-time application fee (minimum $250) for existing users has been waived if the application is received by March 1, 2022, but annual rental fees are not waived and are charged from March 1, 2016 for existing groundwater users. Fees vary based on the purpose and volume of water used. If you submit by the deadline, government will consider when you first used the water to establish your first-in-time, first-in-right (FITFIR) priority. This is important in case of water shortages where the government limits or prioritizes water use.

Wells for domestic purposes are exempt from licensing and are for household use by occupants of a private dwelling, fire protection, domestic animals, and watering a private lawn up to 1,000 m2 in size.[5] See: gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells for information on constructing new wells in B.C.

### Surface Drainage

Similar to groundwater use, surface water use is regulated by the Province of BC and a water use licence is required to extract and divert water for irrigation. In some areas, all available water licences have been allotted and no new licences have been approved in recent years,

4 gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/water-sustainability-act
5 portal.nrs.gov.bc.ca/web/client/-/existing-use-groundwater-licence-application

and therefore the Ministry of Forests, Lands, and Natural Resource Operations should be contacted to confirm availability of additional license. See gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights for more information on water rights.

**Municipal Water**

Municipal water connections may be used for agricultural irrigation; however, this varies in different municipalities, and should be confirmed with your municipality. Under certain circumstances the municipality may require the laowner to upgrade portions of the water distribution system (i.e. on the city side) so that there is sufficient water capacity to service the land. The cost for upgrades vary, but can range from $20,000 to a million dollars. Alternatively, the municipality may object to water distribution system upgrades from the city main to your property if doing so will negatively impact other properties farther down the line.

## 2.7 - FINANCIAL CONSIDERATIONS

Determining the cost of irrigation solutions to be implemented is complex. Once all solutions that can be used to improve irrigation are identified, the next step is to figure out which solution(s) will provide the largest benefit(s) at the lowest cost. While infrastructure purchases will be roughly the same for all farmland, there will be a wide range of costs for labour depending on the resources available. For example, for farmland without access to an onsite bulldozer, constructing a detention pond will require the bulldozer to be rented, possibly with a requirement that the operator of the bulldozer provide the labour, and transport to and from the site.

Costs of materials for irrigation solutions vary from year to year and sometimes within the season. Costing should be conducted by developing a supply list and contacting local suppliers.

## 2.8 - NEXT STEPS

Based on the previous section, you have likely developed a list of methods to increase either the peak demand or the total available water volume for the land, if there is a water shortage. Once the rough estimate is established for each potential option, then decisions need to be made. Does the estimated cost look economically feasible? Does the improvement to the land (either for production or increase in land value) justify the costs? Can your cash flow support the investment? If you have answered yes to all of these questions, then an irrigation plan can be developed and the plan implemented.

An irrigation system needs to be well planned and properly installed to achieve maximum benefit. Small changes to the system can have large impacts to the final flow rate or storage volume. Good installation practices will ensure a reliable system (reducing maintenance costs and headaches down the road). An irrigation plan will also provide better estimates of the materials required and the labour that is expected for the work, and identify the structures and equipment necessary that may not have been identified in the first round of assessments.

For complicated irrigation systems, or substantial changes to as system, a professional should be consulted that can help with the planning process.

# CASE STORY: DROUGHT ISSUES

An environmental steward and promoter of ecological agriculture and local food systems, full-time ornithologistMyles he wanted to make his land in Surrey available for farming. However, past attempts to lease his roughly one-acre plot resulted in difficulties due to lack of water for irrigation during the extended dry periods in the summer.

There is a small watershed just upstream of the property. The water flow has decreased since the '80s because the site was cleared and local municipalities draw heavily from the aquifer. The property has three ponds, filled from subsurface flow, which are connected via pipes with water pumped upstream to the top pond.

Issues arise during dry months when irrigation depletes water in the three storage ponds, and with no source of recharge, they can remain dry until the rainy season. This challenge has stood in the way of Myles' desire to have the land cultivated, but he believes that with the right irrigation method, crop choice, and farmer, his site could be productive.

To date, the creation of irrigation ponds is the only technical fix implemented to address the irrigation water access, but Myles has a few ideas. Using drip irrigation instead of overhead sprinklers used in the past would improve water-use efficiency. This, in conjunction with water-wise crops, could drastically reduce the amount of water needed. Another management idea is to use the Hugelkultur method, a type of semi-vertical cropping system that reduces evaporation losses and increases water retention within the structure. Additionally, he could increase water availability by installing a rainwater capture system from the eaves of a 40' X 60' shop on the property, which could collect into a 20,000 L tank and act as a water reserve.

The challenges to solving this problem are primarily ones of will, time and creativity. Because little can be done to increase the amount of water coming on to the property (other than a rainfall capture system), the challenges become those of management. Myles is confident that with the right amount of creativity and dedication, an ecological solution can be found to make this a productive plot.

## Expert Commentary:

Myles' challenge is common to many properties within BC: access to reliable water. In Myles' case, he is lucky to have a water source on site, though it is not sufficient to meet his agricultural needs. Generally, there are two major options that can be made by property owners who face this type of issue: invest heavily in infrastructure upgrades on the property, or rely on a farmer to develop farming practices that work with what the property has to offer.

In terms of infrastructure investments, the following options are available to Myles, though in his case the property already has the infrastructure in place:

- Develop methods to reduce water lost on the site. In this case, it appears that the water fills generally from the lower pond, which is then pumped up to the upper ponds for storage. One option is to line the upper ponds (ie. Storage ponds) with some type of impermeable liner (clay, bentonite mix, or high-density polyethylene liner) so that no water is lost due to infiltration. In this case, the upper pond is already lined, so there should be minimal water losses at that location.
- Given that the water can be filled with subsurface flow, a well can be installed to pump water from the ground, either on demand or to the upper ponds for storage. There already is a well on site, which is 250+ feet deep and pumps at 3 gallons per minute.
- Add additional water collection and storage infrastructure (as already described by Myles).

The second option is to use farming practices to effectively stretch the available water as far as possible. As Myles has already considered, the following are potential solutions:

- Use crops or cropping methods that required limited water. There have been studies on dryland farming that found certain crop yields can be higher using dryland farming than conventional (i.e. irrigated) methods.
- Farm in the lower areas of the property, which likely have a higher moisture content, longer into the growing season.
- Build soil health across the farm, especially with the goal of increasing available water storage. This can be done by increasing soil organic matter through incorporation of crop residues, composting and minimizing tillage. Hugelkultur, unproven in this area may be worth trying on a small scale.

One of the challenges that Myles would be faced with is finding a solution that is financially viable for the farmer involved. Though there are many farming practices for arid conditions, many methods take will, time and creativity (as Myles has already identified). It is often the case that this comes at the expense of the farmer's net income.

Photo by Olga Lansdorp

# CASE STORY: LACK OF WELL CAPACITY

Last summer, Surrey landowner Lionel Wessell noticed that the pump from his well was constantly running. This was unusual as well as expensive, with Hydro bills running upwards of $1,000. The water serves both his household and a farm that leases the property.

Upon inspection, Lionel determined that the pipe bringing water up 400 feet from the bottom of the well had split. Much of the water was leaking out, and so the pump was not able to efficiently transport water to the surface. The issue was not that the well was running dry; rather, it was because the pipes were split, and leaking water.

In October of 2018, Lionel brought in a crane to fix the problem, pulling out section after section of pipe and replacing it with a new line. He is optimistic about the capacity for his new infrastructure to support his household and a farm this summer, and is happy to note that his current tenant farmer is doing all they can to reduce water use: using drip irrigation as well as watering at midnight to minimize water loss to evaporation.

He notes that it would be nice to have a city water line as a backup in case the well runs into issues in the future. However, the cost of bringing in city water is prohibitive (upwards of $60,000), and even if the city line were put in place he would still have to pay for the water. He is curious to learn more about rainwater catchment systems, but has some questions regarding the safety of the water after sitting stagnant for several months.

## Expert Commentary:

Wells are common sources of water in many parts of British Columbia and in some cases the only source of water on a property. Though this property is only 310 m away from a city water main, the responsibility for connecting a property to the city's water system falls on the property owner. If upgrades to the regional system are required due to the new connection, this must also be covered by the property owner. Given that there appear to be 10 properties along the same road as this property with no City water connection, one option is for the cost of the work shared amongst 10 owners. Though such work can be considered costly for some, it can add to the value of the property.

Rainwater catchment systems are an option for collecting, storing, and using rainwater. However, this type of system is not ideal for agricultural purposes in B.C., where most rainfall occurs in the winter months when additional water is not required. When the water is needed in the summer months there is not enough rainfall to collect and store. As well, the size of storage required for farming is not feasible: 1/4 acre of cultivated land can require up to 200 m3 of irrigation water. This volume would be impossible to store in a conventional storage tank, though perhaps feasible in a detention pond.

Such systems are better suited to areas that have regular rainfall during the growing season (e.g. prairies with convective precipitation). Water safety is a concern for stored water, but can be addressed in a number of ways (sterilization through chlorination or ultraviolet lights) or through application methods or use (e.g. drip irrigation, not used for washing vegetables or other consumption).

Photo by Sara Dent

# SECTION 3.0 - ASSESSING DRAINAGE

Farming can be challenging when the fields do not dry out enough to let you 'get onto the land'. Wet land can also have a detrimental effect on crop production (Figure 4). The reasons for drainage issues can be complex. In order to solve drainage issues, you first need to understand how water gets onto the land, what the water does once on the land, and why the water is not leaving the land at the rate you need in order to farm.

Drainage problems on farmland can be a challenge because:

- Most plants and crops cannot successfully germinate, grow or thrive in saturated fields;
- Tilling very wet fields can lead to compaction of the soils, including creation of a hard pan, clumping soil, and/or loss of soil structure, leading to surface ponding of water; and
- Wet soils also have low soil strength, making it hard to get equipment into the field (e.g. tires spinning out or equipment getting stuck).

Poor drainage can decrease your workable season by limiting access to the farm when fields are saturated, making it hard to grow vegetables that take many days to mature (+100 days, e.g. potatoes), and/or limiting farm income early or late in the season (i.e. spring/fall). Not being able to access fields during the "moist shoulders" of the growing season also limits your ability to reduce irrigation needs by choosing crops that can utilize shoulder season rainfall.

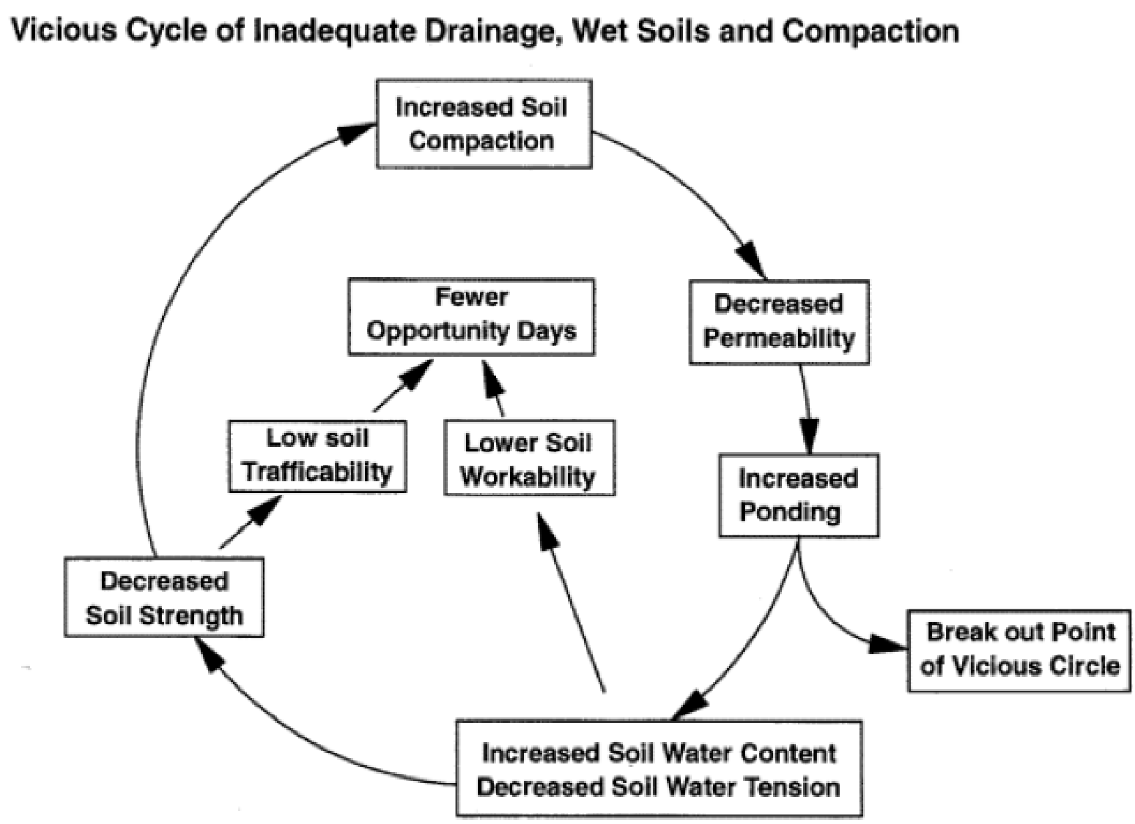



Figure 4: Impacts of Drainage (Jan DeVries, B.C. Agricultural Drainage Manual)

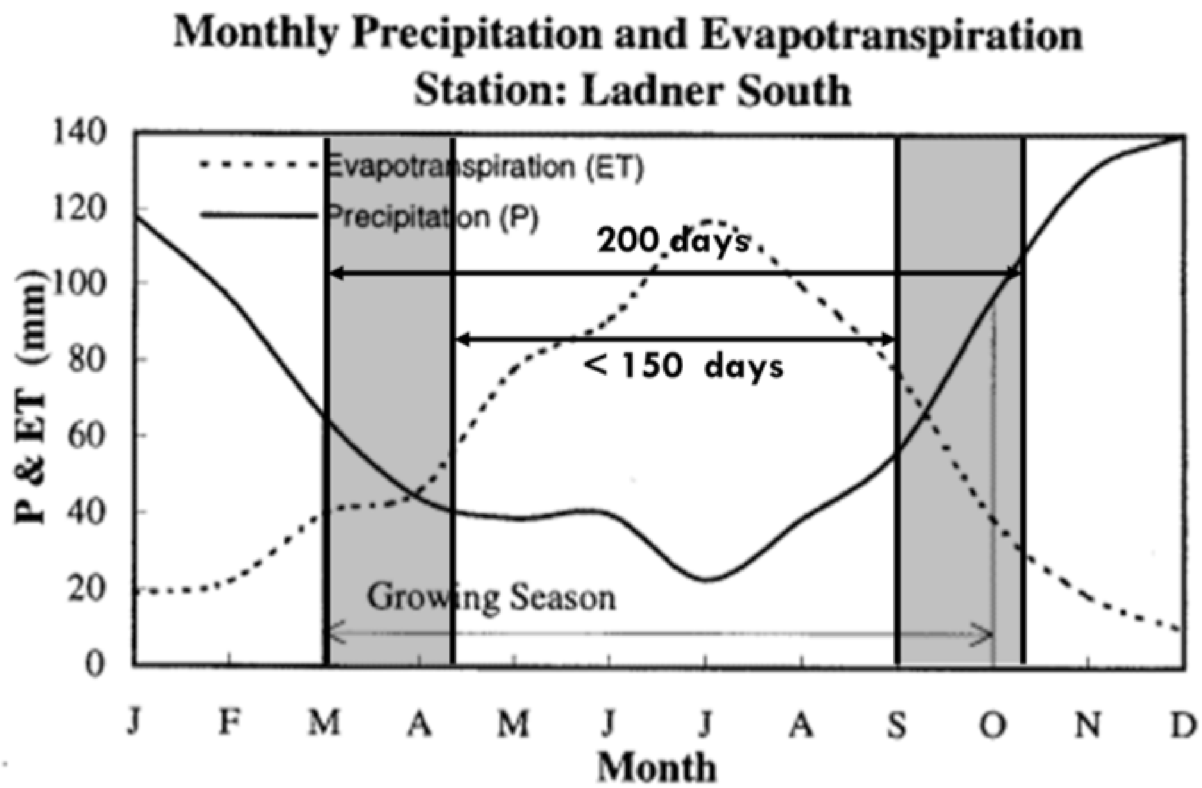
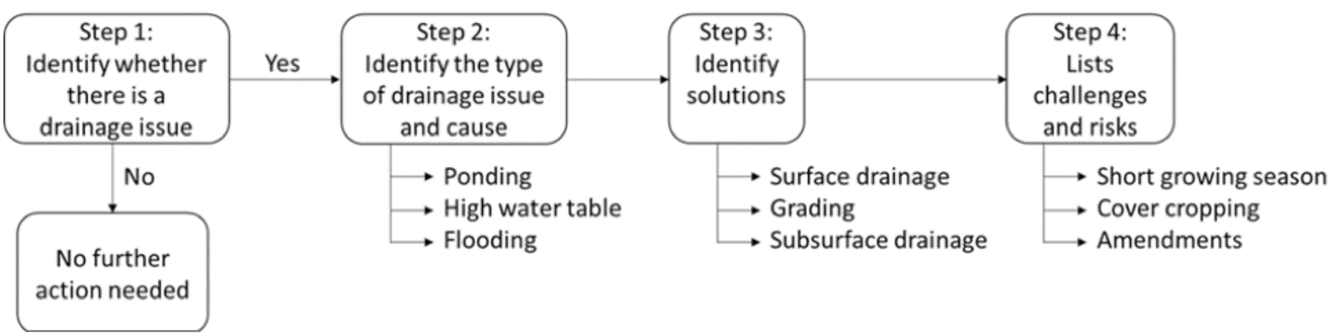



Figure 5: Annual Precipitation vs. Evapotranspiration at Ladner (B.C. Agricultural Drainage Manual)

In this chapter we will work through the following steps:




# 3.1 - AN INTRODUCTION TO DRAINAGE

Drainage is difficult to accurately assess, especially for a single piece of land, because there are many factors that affect the movement of water through land. For the purpose of this manual, we will take a simplistic approach to drainage. To understand drainage, you'll need to understand of all incoming water, water storage, and outgoing water, which is represented in the following diagram:

**Incoming Water**

- Precipitation
- Surface Runoff
- Groundwater
- Controlled Additional Sources

→ Land (storage) →

**Outgoing Water**

- Evaporation
- Transpiration
- **Drainage**
  - **Groundwater**
  - **Surface Runoff**

Generally, water comes onto the land in four different ways:

- **Precipitation:** water comes onto the site in the form of rain or snow.
- **Surface Runoff:** water comes onto the land along a surface route; for example, from adjacent land, or from a creek that runs through the property.
- **Groundwater:** water found in aquifers, underlying soil, bedrock or parent materials. This water may represent a water inflow to the farmland when local groundwater table is shallow enough to be accessible to crops or even come to the surface on the farm. However, groundwater may also be an outgoing water when water is lost from the farm by percolating into the groundwater system.
- **Controlled Additional Sources:** water that is brought into the farm in a controlled method and not dependent on climate or weather. For example, trucked in or pumped from an offsite water body or groundwater well.

Excess water can be stored on the land as surface ponding when water coming onto the land exceeds outgoing water. Water can also be stored in the soil as capillary water or gravitational water. Capillary water is brought into the soil from either infiltration or capillary rise from the water table and is held within the soil structure even if drainage capacity is present. Gravitational water infiltrates into the soil, filling the air spaces required for plant growth. Drainage works to remove the gravitational water.

Water leaves farmland in three different ways:

- **Evaporation:** water lost from the land by the process of evaporation.
- **Transpiration:** water lost from the evaporation of water that has moved through plants on the land.
- **Drainage:** water that moves off the land via two mechanisms:
  1. **Surface Drainage:** excess surface water that moves off the land via a pumped or gravitational outlet; or
  2. **Groundwater:** water that infiltrates the soil below the crop's usable levels.

# 3.2 - COLLECTING INFORMATION

Calculating drainage capacity of a parcel of land is complex and depends on many factors, including soil type, subsurface conditions, subsurface hydrology, surface hydrology, climate, and more. As calculating the drainage capacity of a piece of land is not practical, drainage problems are identified by collecting information about the farm based primarily on visual observations. This manual was developed to support a screening level assessment of a parcel of land.

A useful first step is to locate the farm of interest on the local soil map and refer to the soil description of soil characteristics to see if drainage is a serious issue. The Soil Report for the Lower Fraser Valley[6] is augmented by the Soil Management Handbook for the Lower Fraser Valley[7] which gives more detailed information on soil drainage requirements. If complex drainage issues are found, a professional familiar with the local area should be contacted for further assessment.

A screening level assessment can be done by observations of the land as well as discussions with the land owner, previous farm operators, local farming associations, and neighbouring residents and farmers. This information should be based on observations throughout a full year or a number of years where possible. Tool such as Google Maps and Google Earth can provide some historic mapping information to compare across years and seasons. The following list provides visual observations that are indicators of drainage problems:

- presence of water loving plants (eg reeds, willow, hardhack etc) may indicate ponding
- ponded surface water
- water movement through land (stream or overland flows)
- high ditch or creek levels
- wet spots or flowing water
- ruts or damage to fields produced by livestock or machinery
- water table location
- difficulties accessing the fields
- unsatisfactory crop yields
- poor crop quality
- poor crop response
- cloddy soil conditions after tilling

## 3.2.1 - UNDERSTANDING THE RELATIONSHIP BETWEEN YOUR OBSERVATIONS AND CLIMATE

In order to make sense of the information gathered on a piece of land, it is also necessary to understand the weather patterns that the observations are based on. For example, observations during dry periods may not show drainage problems that are present, while observations during wet years may show drainage problems that do not normally occur.

To understand how changing weather patterns over time may affect observations and assessment of drainage problems, you can compare monthly precipitation patterns over the observation period to average precipitation patterns.

In this step you will estimate how weather patterns over the observation period compared with average climate patterns:

1. Find the farmland coordinates for the property in question.
   Coordinates can be found using Google Earth™ if not known.

6 sis.agr.gc.ca/cansis/publications/surveys/bc/bc15/index.html

7 gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/soil-nutrients/610000-1_soil_mgmt_handbook_fraservalley.pdf

2. The Canadian Ministry of Environment has made a comprehensive historical database that can be used to assess the historical weather and average climate for climate stations throughout the Metro Vancouver and Fraser Valley region. Use this website to determine the climate station most representative of the farmland. Enter the farmland coordinates in degrees, minutes, seconds into the following website: climate.weather.gc.ca/historical_data/search_historic_data_e.html
3. Select the climate station with the following characteristics:
    - Has monthly data interval. Each station may have hourly, daily and/or monthly data. if monthly data is not available daily data of each month will have to be summed to convert to monthly data;
    - Has climate data over the observation period;
    - Has a similar elevation to the farm; and
    - Ideally is within 25 km of the farm.

4. Estimate the average monthly climate of the farmland. The University of British Columbia has made a comprehensive climate database, which estimates monthly climate variables for any location in BC. Use this calculator to determine monthly climate for the farm. Select Normal 1981_2010 for the best representation of average climate at the farm (Figure 6).
5. Compare monthly climate norms from the nearest climate station to data from the period of observations. Was it dryer, wetter or normal than average?

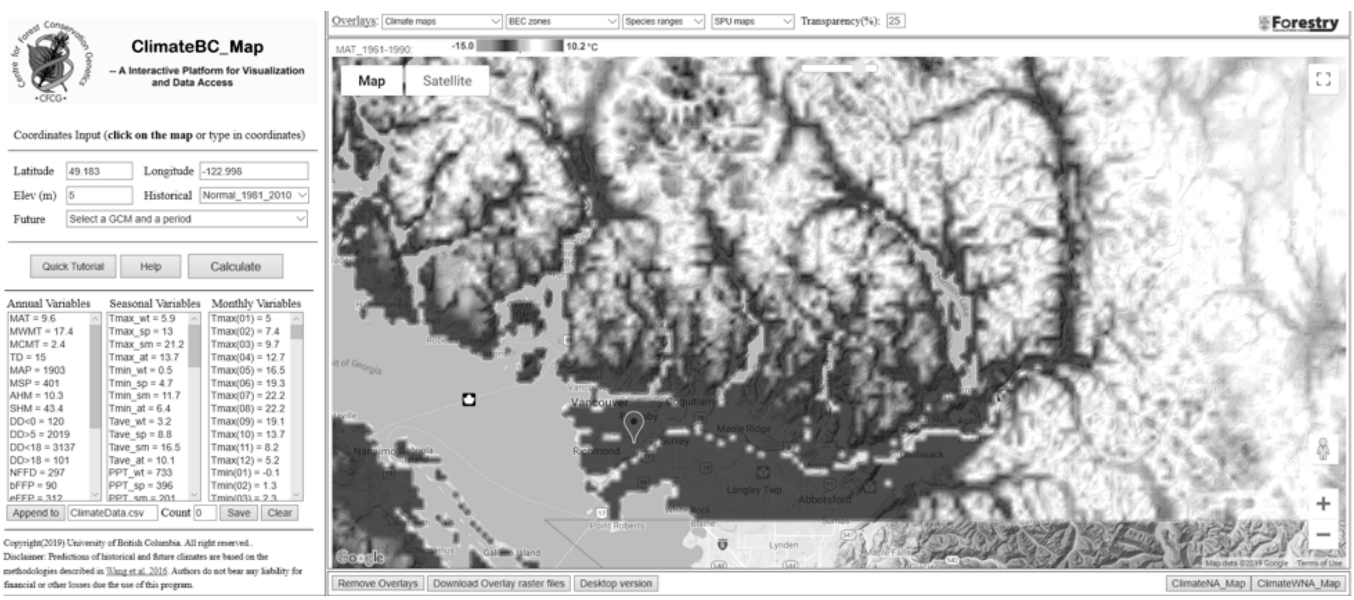



Figure 6. Climate BC mapping tool to explore location-specific climate norms.

Climate change is a well-known challenge for future planning. Broadly speaking, climate change on farms may be characterised by wetter winters, drier summers, and more severe short duration events (1-day to 5-day storm events). A further description of climate change can be found in Chapter 5. It is important to keep climate change in mind when assessing current and future drainage issues on a parcel of land, as drainage may become an increasing problem and future planning will help with adaptation and farm resilience.

## 3.2.2 - TOPOGRAPHY REVIEW

The topography of the farmland should be reviewed to look for:

- Low lying areas with no outlet for water to drain. Could be a good place for a pond to store water.
- Large catchment areas upstream of the farmland that may contribute to flooding.
- Streams or gullies adjacent

A simple, free way to review rough farm catchments is Google Earth™; although the resolution may not identify all issues. Review of the topography followed by a site visit is recommended.

# 3.3 - IDENTIFYING DRAINAGE ISSUES & CAUSE

Before deciding on potential solutions, it is essential to identify the type of drainage issue by looking at where the water is coming from and how the water is (or isn't) getting off the land. It is important that you don't make assumptions in order to ensure you don't end up implementing the wrong solution for an issue that has been mis-identified. If you are uncertain about some of the questions, please consult a professional.

Figure 7 shows how the three types of drainage all display ponded surface water. However, the cause can be quite different. The flow chart in Figure 8 can help determine the cause of the ponded surface water, which is required in order to develop a solution.

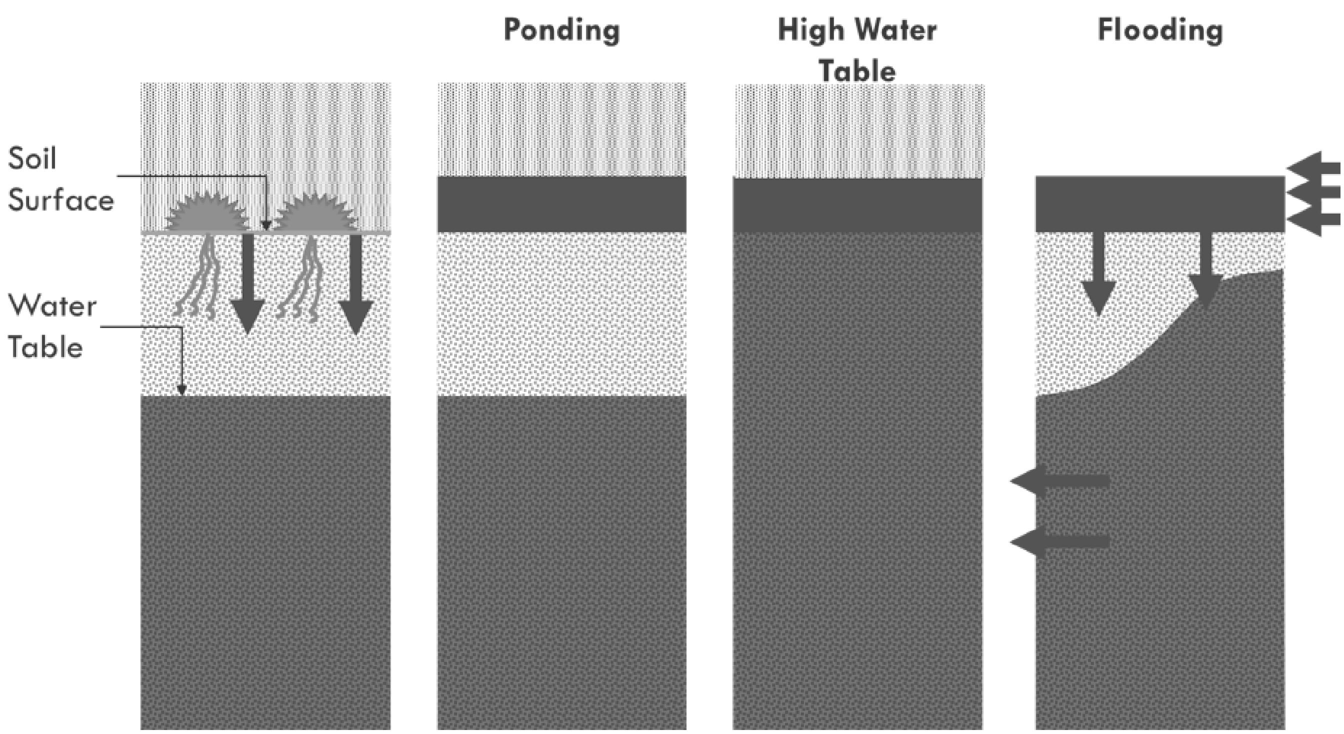



Figure 7: Types of Drainage Issues.

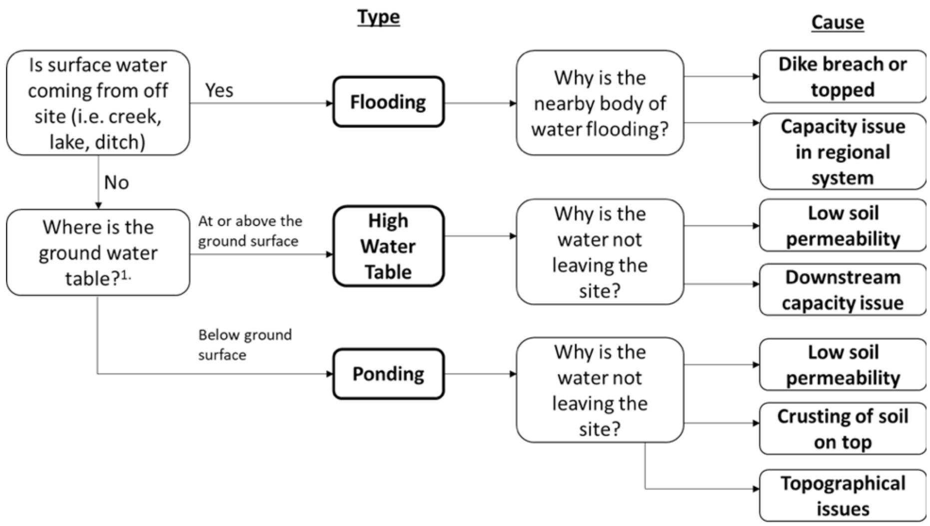



Figure 8: Flowchart to Identify Cause of Drainage Issue.

## Description:

**Flooding:** Generally occurs when water comes onto farmland from outside surface sources (e.g. lakes, streams, and ditches). This can occur during the spring freshet (snow melt at higher elevations reaching the regional river system, such as the Fraser River), and large rain events. Other sources of flooding may exist (e.g. inadequate regional drainage pump stations, defective flood control gates, etc).

**High Water Table:** Generally occurs when there is inadequate drainage capacity on the farm or within the local drainage network. This occurs when the water system is 'backed up', causing water to stay on site. To find the most effective corrective actions, it is important to determine whether the cause is on the farm (low permeability of the soil) or off the farm (ditch system is overwhelmed or undersized).

**Ponding:** Generally occurs when there is a crust of soil on the top of the ground that prevents water from infiltrating into the soil or when there are downstream obstructions to drainage (e.g. higher topography). When water ponds on top, it may run off the surface leaving deep furrows in the soil, wash soil away from the fields or limit access to the farm. Ponding is most problematic during high rainfall events that can wash out parts of the field.

# 3.4 - DEVELOPING DRAINAGE SOLUTIONS

Once you identify the cause of the drainage issues, you can look at possible solutions (Table 4). Drainage improvements range from sophisticated designs, requiring professional expertise, to simple farming practises. Drainage often requires a multifaceted approach to be effective. For example, subsurface drain tiles will not function without a ditch network to form an outlet.

Drainage improvements are often most effectively implemented in an iterative manner where the drainage solution with the best cost benefit ratio is implemented, reviewed, then improved with additional improvements if required. For example, a ditch network being developed to remove excess surface water. Once completed, cover crops or soil amendments could be used to improve the soil structure that was damaged by poor drainage.

# Table 4: Farm Drainage Solutions

| TYPE | DESCRIPTION / USES | DESIGN CRITERIA | PROS / CONS |
|---|---|---|---|
| Ditch | Excavation of a channel (typically trapezoidal in shape, meaning with a flat bottom and sloped edges) used to forms the backbone of all farm drainage. Ditches are typically required for all drainage issues:<br><br>• To intercept water from upstream catchments (minimize flooding)<br>• Create outlets for low lying areas (reduce ponding)<br>• To act as an outlet for subsurface drainage (high groundwater table)<br>• To lower groundwater levels when designed correctly | • Requires grade (ground slope) of 0.1 to 0.3% to be effective.<br>• Slopes greater than 0.3% require professional erosion protection design.<br>• Side slopes should be 2.5H:1V (for every 2.5 m of side slope the vertical distance should be 1m . Slopes greater than this require evaluation of soil slope stability.<br>• Require outlet elevation to be above the local water table to prevent backwatering from occurring | Advantages:<br>• Low initial cost<br>• High capacity<br>• Easy to construct<br><br>Disadvantages:<br>• Loss of usable land<br>• High maintenance requirements<br>• May cause soil erosion<br>• Farming equipment cannot cross without further infrastructure |
| Grassed Waterway | Excavation of a channel with shallow side slopes:<br><br>• Create outlets for low lying areas (reduce ponding)<br>• Intercepts water from upstream catchments (minimize flooding) | • Require grade (ground slope) of 0.1 to 0.3% to be effective.<br>• Slopes greater than 0.3% require erosion protection design by professional.<br>• Side slopes should be a minimum of 5H:1V for small farm equipment to cross. 10H:1V will allow all machinery to cross. | Advantages:<br>Low initial cost<br>• Low maintenance once vegetation is established<br>• Easy to construct<br>• No loss of usable land<br>• Farm equipment can cross<br>• High capacity<br><br>Disadvantages:<br>• Vegetation can be difficult to establish<br>• Not suitable as drainage outlet<br>• May cause soil erosion if not correctly designed |

| TYPE | DESCRIPTION / USES | DESIGN CRITERIA | PROS / CONS |
|---|---|---|---|
| Land Grading | Shaping of soil surface to improve drainage and reduce or eliminate low lying areas where water may pond. Can involve land leveling or, in steeper terrain, terracing. Typically constructed by cutting high spots to fill in the low areas. | NA | Advantages:<br>• Easy to construct<br>• No maintenance<br>• Designed correctly can reduce erosion<br><br>Disadvantages:<br>• Can expose subsurface in deep cut areas<br>• Covering topsoil with subsoil can cause reduced crop yield<br>• Can cause soil compaction<br>• Can exacerbate soil salinity problems |
| Dykes | Development of soil ridges or berms along land margins, ditch edges or streams to prevent flooding. For this report dykes are considered to be structures that permanently hold water or are designed to hold back water greater than 0.5 m. Dykes are usually maintained by a local dyking authority. | To be determined by a registered professional | Advantages:<br>• Can prevent flood waters from entering farmland<br><br>Disadvantages:<br>• Can lead to downstream and/or upstream impacts that are difficult to foresee without significant expertise.<br>• High cost for design<br>• High maintenance |
| Subsurface Drainage (drain tile) | Lowers the water table elevation using rows of perforated pipes to transport excess ground water to a pumped or gravitational outlet. | Design based on soil characteristics, topography, planned crop root depth. | Advantages:<br>• Lowers water table improving crop yield.<br>• Reduces soil salinity<br><br>Disadvantages:<br>• High initial cost<br>• Requires suitable outlet elevation or pumped system |
| Soil Improvements: Soil amendmentts | Soil Amendments are added to the soil to improve soil structure, therefore reducing improving infiltration capacity and reducing ponding. Examples include:<br><br>• Solid manure or compost applications timed to prevent nutrient loss<br>• Lime or gypsum applications to alter hardpan minerals. | NA | Advantages:<br>• Low cost<br>• No maintenance<br><br>Disadvantages:<br>• Can lead to loss of nutrients to aquatic environment |

| TYPE | DESCRIPTION / USES | DESIGN CRITERIA | PROS / CONS |
|---|---|---|---|
| Soil Improvements: Use of cover crops | Cover crops are planted in a crop rotation system or in the off season of the primary harvest crop. Cover crops are used to:<br><br>• Reduce soil erosion<br>• Improve soil structure to increase infiltration rates<br>• Retain nutrients against leaching and foster good soil health<br>• Provide wildlife habitat | • Planted in late summer or early fall after main harvest is completed<br>• Crop selection will depend on the date of harvest of the main crop. Typically, cereal grasses, legumes, and forage grasses.<br>• Crop rotations will be designed based on soil conditions, the harvest crop, and the proposed cover crop | Advantages:<br>• Low cost<br><br>Disadvantages:<br>• Can be an alternate host to crop pests and diseases<br>• Termination of cover crop may complicate soil preparation for seeding cash crops. |
| Soil Improvements: subsoiiling. | Subsoiling is the loosening of soil below the surface to improve soil structure and increase rooting depth.<br><br>Used in conjunction with surface drainage to break up hardpan causing perched water tables (an accumulation of groundwater that is above the water table in the unsaturated zone). | NA | Advantages:<br>• Low cost<br>• Quickly breaks up hardpan layers<br><br>Disadvantages:<br>• Can increase erosion<br>• Can damage soil when conducted below compacted layer or the rooting depth of the crop<br>• Regular, frequent subsoiling costs energy, time and money, and should not be seen as a replacement for good soil management. |

# 3.4.1 - DITCH DESIGN

The goal of a ditch system is to either divert water prior to entering the farmland or to remove the water quickly after it has entered the farmland. Ditch design can be a complex process as the design will depend on the farm's soil type(s), topography, climate, and the suitability of an outlet for the ditch system. Additionally, designs may require erosion control and regulatory compliance (e.g. Department of Fisheries and Oceans Regulations). Additional resources for ditch design are included in Table 5. Ditches are designed to pass specific peak flows, estimated based on regional drainage criteria:[8]

- To remove runoff from the 10-year, 5-day storm, within 5 days in the dormant period (November 1 to February 28);
- To remove runoff from the 10-year, 2-day storm, within 2 days in the growing period (March 1 to October 31);
- Between storm events and in periods when drainage is required, the base flow in

8 Resource Management Branch, Drainage Fact Sheet: Agricultural Drainage Criteria (BC Ministry of Agriculture, Food & Fisheries, 2002), agf.gov.bc.ca/resmgmt/ publist/500Series/535100-2.pdf

channels must be maintained at 1.2 metres below field elevation (Figure 5); and
- The conveyance system must be sized appropriately for both base flow and design storm flow.

There are two types of ditches. Grassed waterways are shallow ditches with side slopes gentle enough to allow vehicles to drive through and for farming to take place throughout. The other, more typical ditch, is constructed with a trapezoidal channel with side slopes of 3H:1V.

Depending on the flow rate of the water to be transported through the ditch system, the design process can be complex or simple. Ditches are often constructed without regard to design in locations with slopes of 0.1% to 0.3%, small watershed areas and outlets with clear drainage paths identified in the topography review. While this approach is not recommended, it can provide the necessary improvements. If gradients are greater than 0.3%, the watershed area is large, or the outlet is not easily defined then the design should be reviewed by a professional engineer who will review the following:

- alignment of the ditch
- watershed area
- storm events used to estimate peak runoff rate
- peak runoff rate calculations
- ditch size for design flow and velocity
- erosion control design
- side slope stability
- ensure regulatory hurdles are accounted for (e.g. DFO)

## Table 5: Ditch Design Resources

| RESOURCE | LINK |
|---|---|
| Storm event intensities from a 5-minute storm to a 72- hour storm in zones throughout Metro Vancouver can be found in the drawings of the linked report | metrovancouver.org/services/liquid-waste/LiquidWastePublications/RegionalIDFCurves2009.pdf |
| Province of British Columbia Drainage Management Guide | gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/drainage/drainage-management-guide |
| Province of British Columbia Sediment Control During and post construction | gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/soil-nutrients/600-series/641300-1_sediment_control-drainage_guide_factsheet_no8.pdf |
| Province of British Columbia New Ditch Construction Factsheet | gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/water/drainage-management-guide/533530-1_new_ditch_construction-drainage_guide_factsheet_no6.pdf |
| Regional Agriculture Drainage Criteria | gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/water/drainage/535100-2_agric_drainage_criteria.pdf |

### 3.4.2 - SUBSURFACE DRAINAGE

The goal of subsurface drainage is to lower the water table to remove excess water that has infiltrated into the soil, resulting in improved crop production. Design of subsurface drainage systems consists of determining the layout, pattern, depth, and spacing, pipe size, and depth of the pipes. Details of the design process can be reviewed in the Province of British Columbia's Agricultural Drainage Manual.[9]

Subsurface drainage will typically also be designed in conjunction with a ditch system to convey the excess water downstream. If a suitable outlet is not available the system will not be feasible without pumping systems.

Due to the complexities of the design and expense of the installation of these systems, it is recommended to contact a professional both to understand the design and the possible costs. Typical costs range from $2,500 to $3,750 per hectare ($1,000–$1,500 per acre) depending on the farm's location, layout, and spacing requirements.[10]

## 3.5 - FINANCIAL CONSIDERATIONS

Determining the final cost of drainage solutions to be implemented is a complex process best done by a professional. Most on-farm drainage works are carried out by custom contractors who would be able to offer a cost estimate based on the system design.

## 3.6 - NEXT STEPS

Based on the previous section, you have likely developed a list of methods to improve drainage. Once a rough estimate is established for each potential option, then decisions need to be made. Does the rough cost look economically feasible? Does the improvement to the land (either for production or increase in land value) justify the costs? Can your cash flow support the investment? If you have answered yes to all of these questions, then a drainage plan can be developed and the plan implemented.

A drainage system needs to be well planned and properly installed to achieve maximum benefit. The correct solutions need to be implemented to ensure the maximum drainage improvements (and ideally reducing maintenance costs and headaches down the road).

A drainage plan will also provide better estimates of the materials required and the labour that is expected for the work, and identify the structures and equipment necessary that may not have been identified in the first round of assessments.

For complicated or substantial drainage improvements, a professional should be consulted who can help with the planning process.

---

9 gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/drainage/agricultural-drainage-manual

10 bcagclimateaction.ca/wp/wp-content/media/FarmPractices-Drainage.pdf

# CASE STORY: HIGH WATER TABLE

Tucked away in Richmond, BC, between Highway 99 and Sidaway Road, is a two-acre parcel of land that Rose Dykstra is currently leasing to grow flowers for her business, the Front Yard Flower Co. Karly Pinch is also familiar with the land; from 2015-2018 she grew vegetables there for local markets as Shady Acre Farm.

Drainage is a major issue in Richmond, where the groundwater table is high. Both Karly and Rose agree that this limits their operations, making it difficult or impossible to grow perennials, delaying access to fields in spring, and limiting the ability to harvest fall crops and prepare fields for winter. Karly experienced a catastrophic year in 2017, when fields were still too wet to walk on or till until early June, and weeds got a head start.

The landowner has helped implement several solutions, installing a small ditch running North-South along the property, with several culverts going to a larger ditch on the neighbour's property. Karly used raised beds, Rose is now doing the same. Rose is in her first season on the land, and plans to use natural high spots for perennials. She is considering installing a pond in the low spot of the property to gather excess water.

The larger issue is that some of the neighbours have built up their land by several feet, and the neighbour's ditch to the east is filling in with vegetation (and presumably soil), making it ineffective as a conduit for excess water. This ditch is not pumped, so when the water table is high there is nowhere for water to go.

As a solution to the multiple issues impacting drainage, Karly and Rose proposed increasing the level of the farm by bringing in fill from another site. If the site were raised a few feet, the height of the water table would no longer limit the farm operation; however, money and red tape are obstacles to implementing this solution.

## Expert Commentary:

A phone call to The Richmond Public Works Service Centre (see Table 6) confirmed that the municipal ditch adjacent to the farm connects to pumping stations on No. 6 and Siddaway Roads and that its water level is low enough to provide an outlet for drainage. Cleaning out the ditch on the east side of the property should facilitate the removal of excess water. However, because the outlet ditch is on the neighbour's property, they must agree to having it cleaned out.

Installing subsurface drains connected to a pumping system could be explored after cleaning the outlet ditch; however, it is unlikely that this would be financially viable for a farmer leasing the land and the landowner would have to invest directly in the project. Alternatively, the farmer could be given long term tenure such that the cost of subsurface drainage could be amortized.

With the site conditions and financial considerations, the most feasible option is to use farming techniques: accept a shorter growing season, and prepare raised beds for the following year in the fall and cover with a silage tarp, so that tilling is not required in the spring.

Photo by Rose Dykstra

# CASE STORY: LOW SOIL PERMEABILITY

Tsawwassen Farm School (TFS) in Delta, B.C. is an organic farm with a focus on mixed vegetables and fruits, pork and egg production. TFS is a collaboration between Tsawwassen First Nation and the Institute for Sustainable Food Systems at KPU. The farm consists of 20 acres of relatively flat land with a predominant soil texture of silt loam, and experiences several challenges due to low soil permeability.

In 2017, Micheal Robinson began managing the farm, after graduating from Kwantlen Polytechnic University (KPU) and interning on a local farm. According to Micheal, the land was previously farmed extensively with heavy equipment, leading to the development of a hardpan in the subsoil approximately 20 cm, (8 inches) below the surface.

The high soil saturation in late winter/early spring impedes staff and students' ability to work the soil as early as comparable farms in the region. The long interval of saturated soil limits the farm's production season. Additionally, the low soil permeability has hindered attempts to establish certain perennial crops.

- Michael and the farm stafff have made several attempts to mitigate the low soil permeability:
- In 2014, the farm installed drain tiles on a quarter of the land, with 10 meter (30 ft) spacing between tiles.
- Farm managment involves a rotation of livestock, cover crop and annuals production to build up soil organic matter in ordet to minimize the hardpan and improve soil structure.
- A subsoiler implement is used in the field to physically break up the hardpan.
- TFS has experimented with the incorporation of tillage radish in their cover crop mix but have discovered complications with pest management in brassica production.

Michael says that the challenges to solving the issue of low soil permeability include the high cost of alternative management, and the considerable time it takes to rehabilitate the soil by building up soil organic matter.

# Expert Commentary:

Many farmers in this area (i.e. Richmond and Delta) suffer from similar issues. Their soils are high in silt and clay, and have been farmed with heavy equipment without adequate subsurface drainage.

The steps TFS has taken are those generally recommended to improve onsite drainage conditions (e.g. subsoiling, drain tiles, increasing organic content in the soil to improve soil structure, etc.); however, they are finding that these methods are not sufficient to address the issues on the farm.

The following are additional tasks that can be undertaken to improve the conditions on the farm, in addition to the work already being completed:

- Install various surface drainage methods to remove excessive water from the plot before it enters the groundwater table. This includes installing additional ditches and grading the land to minimize low areas and ponding.
- Continuation of subsoiling, making sure that soil moisture is in the proper range, not too wet, to ensure shattering of the plowpan.
- Use soil amendments such as compost, manure, or cover crops to improve soil structure.
- Install a drainage pumping system to pump water off the site faster.
- Assess regional drainage system for capacity to accept farm runoff. The feasibility and ultimate success of any on-farm drainage improvements will depend on the effectiveness of the municipal drainage system.

Given the size of this land (in the order of 20 acres), many of the above recommendations will likely cost a substantial amount, which may pose a significant challenge to the farm, especially if the tenure is too short to amortize large investments in land improvement. Importantly, the amelioration of poor soil structure and soil compaction may not happen in short order and practices initiated by TFS may need more time to fully remediate the effects of past farming practices.

Recommended resources: The B.C. Agricultural Drainage Manual is an excellent resource that addresses methods to improve drainage.

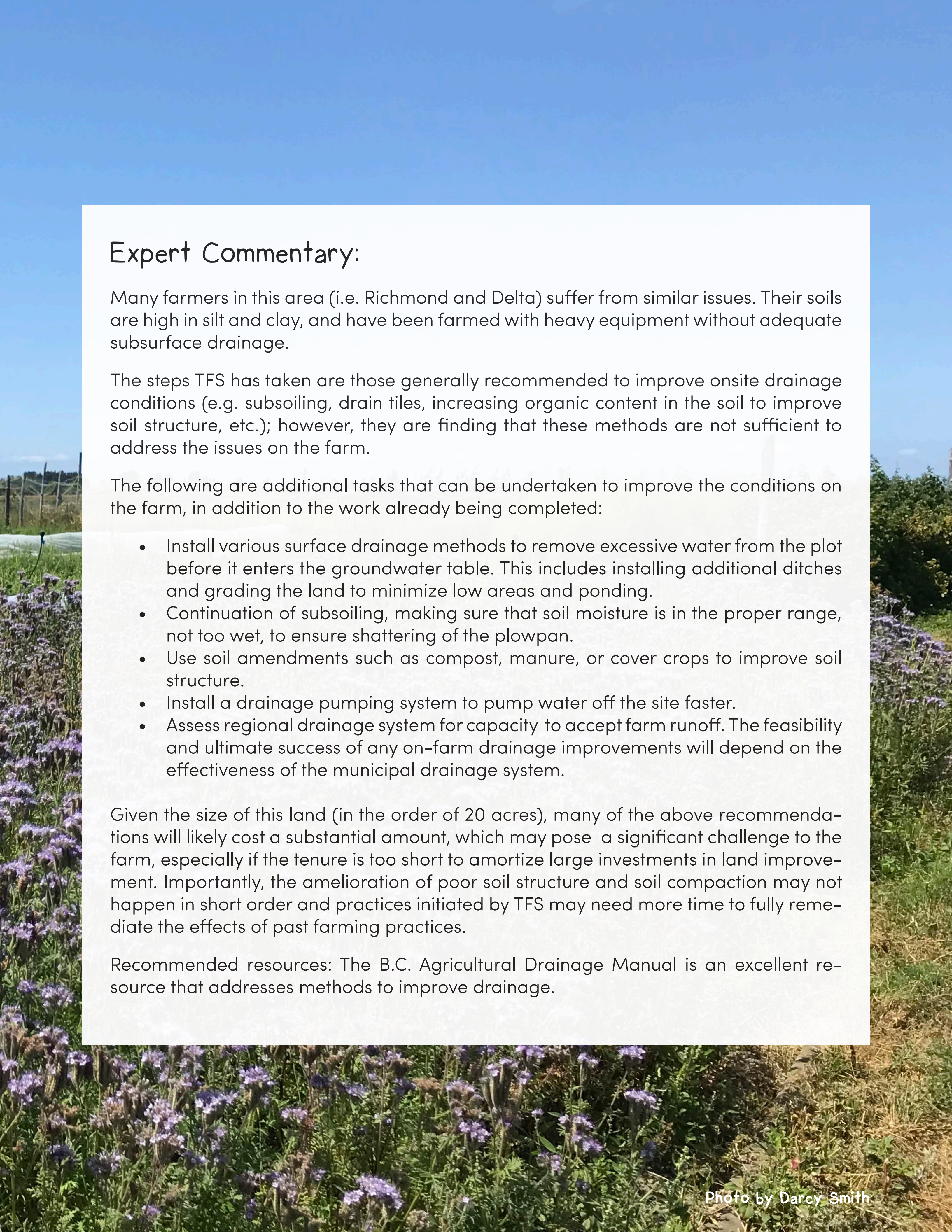


Photo by Darcy Smith

# SECTION 4.0 - BYLAWS, REGULATIONS, & RESOURCES

## 4.1 - BYLAWS AND REGULATIONS

There are numerous bylaws impacting agricultural activities that farmland owners and farmers should be aware of before embarking on major changes to the irrigation and drainage setup on a farm. These include:

- Agricultural Environmental Management Regulation: https://www2.gov.bc.ca/gov/content/environment/waste-management/industrial-waste/agriculture
- Agricultural Land Commission and Agricultural Land Reserve: https://www.alc.gov.bc.ca/alc/content/home
- Municipal Bylaws: Various, please refer to your local municipal website
- Water Discharge Regulation: https://www2.gov.bc.ca/gov/content/environment/waste-management/waste-discharge-authorization
- Water Sustainability Act: https://engage.gov.bc.ca/watersustainabilityact/

## 4.2 RESOURCES

### Table 6: Resources

| ORGANIZATION | CONTACT INFO | SCOPE | NOTES |
|---|---|---|---|
| MUNICIPAL ENGINEERING DEPARTMENTS | | | |
| City of Surrey | General Manager<br>Fraser Smith, P. Eng<br>EngWebmail@surrey.ca<br>https://www.surrey.ca/city-government/608.aspx | Ditch in-fill needed<br>Damaged/blocked culvert<br>Need help finding a water/sewer connection<br>Spill of unknown substance in drainage ditch, storm drain or another waterway | |
| Township of Langley | General Manager<br>Ramin Seifi<br>604-533-6006<br>enginfo@tol.ca<br>https://www.tol.ca/your-township/township-divisions/engineering/ | | |
| Corporation of Delta | Engineering Department<br>604-946-3260<br>http://www.delta.ca/services/water-sewer/common-water-sewer-concerns | | |

| ORGANIZATION | CONTACT INFO | SCOPE | NOTES |
|---|---|---|---|
| City of Richmond | Manager: Bryan Shepherd<br>Email: bryan.shepherd@<br>richmond.ca<br>Public Works<br>Service Centre<br>604-244-1262<br>https://www.richmond.<br>ca/contact/departments/<br>epw/water.htm | | |
| **PROVINCE OF B.C.** | | | |
| BC Ministry of Agriculture | 1 888 221-7141<br>AgriServiceBC@gov.bc.ca<br>https://www2.gov.bc.ca/<br>gov/content/industry/<br>agriculture-seafood/<br>agricultural-land-and-<br>environment/water | | |
| | Petersen, Andrew<br>BC Ministry of Agriculture<br>441 Columbia Street<br>KAMLOOPS, BC<br>V2C 2T3<br>Tel: 250-828-4514<br>Fax: 250-828-4154<br>Email: Andrew.<br>Petersen@gov.bc.ca | Irrigation Industry Association of BC - Certified Professional | |
| | Tam, Stephanie<br>BC Ministry of Agriculture<br>1767 Angus Campbell<br>Road<br>ABBOTSFORD, BC<br>V3G 2M3<br>Tel: 604-556-3113<br>Fax: 604-556-3099<br>Email: Stephanie.<br>Tam@gov.bc.ca | Irrigation Industry Association of BC - Certified Professional | |
| | BC Agricultural<br>Water Calculator<br>bcagriculturewa<br>tercalculator.ca/ | Calculates water needs for farming in BC, based on property location and size. | |
| **OTHER ORGANIZATIONS** | | | |
| BC Agricultural & Food Climate Action Initiative | Director: Emily MacNair<br>Emily@<br>BCAgClimateAction.<br>ca 250-361-5410<br>PO Box 8248, Victoria,<br>BC, V8W 3R9 (mail) | Information, studies, tools and projects on climate change initiatives for farms in BC. | |

| ORGANIZATION | CONTACT INFO | SCOPE | NOTES |
|---|---|---|---|
| BC Agriculture Council | Unit 1 - 2650 Progressive Way Abbotsford, BC Canada (604) 854-4483 info@bcac.ca | Non-profit, non-government organization representing various farm associations in BC. | |
| Investment Agriculture Foundation of BC | PO Box 8248 Victoria, BC, V8W 3R9 250.940.6150 info@iafbc.ca | | |
| Irrigation Industry Association of BC | Kim Schaefer, Executive Administrator PO Box 3066 Mission, BC V2V 4J3 Canada E-mail: iiabc@ irrigationbc.com Phone: (604) 287-8222 Fax: (604) 287-8224 | Irrigation information from industry professionals. | |
| Society Promoting Environmental Conservation (SPEC) | 305 West 7th Ave Vancouver, BC V6K 1Y4 T: 604.736.7732 E: admin@spec.bc.ca | Access to agricultural extension services, including soil health and integrated pest management professionals. | |
| Young Agrarians | Executive Director: Sara Dent farm@youngagrarians.org | Resources for new and young farmers: land access, business mentorship, U-MAP, and more.<br><br>B.C. Land Matching Program | |

# ADDITIONAL RESOURCES

gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/irrigation/irrigation-management-guide

gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/irrigation/irrigation-system-assessment-guide

gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/irrigation/sprinkler-irrigation-manual

# SECTION 5.0 - OTHER CONSIDERATIONS

Climate Change – Climate change is the shift in the state of the climate, which is identified through alterations in climate properties that persist over an extended period (typically decades or longer). This includes expected and unexpected changes in climate due to natural variability or human activity. In British Columbia the impacts of climate change will vary over the season, the following trends are generally predicted.

Temperature increase of 1.3 to 2.7 °C expected by 2050, with projected impacts including:

- Longer growing seasons hampered by more frequent and severe droughts
- Shifting infectious diseases and pests, with effects on health, agriculture and ecosystems
- More frequent and severe heat waves resulting in increased heat-related illnesses

Average annual rainfall is expected to increase from 2% to 12% by 2050, though summers will be drier, with projected impacts including:

- Increased frequency and intensity of precipitation resulting in damage to infrastructure
- Higher risk of wildfires, insect outbreaks and diseases in our forests
- Farmers and ranchers experiencing more frequent and severe droughts, soil erosion and new pests

Up to 70% of our glaciers may have disappeared by 2100, expected to result in:

- Changes in river flows and temperature affecting fish habitat and hydroelectric power generation
- Drinking water decreasing in quality and quantity
- Water shortages increasing competition between various water users

Sea level is expected to continue to rise along most of B.C.'s coast, with projected impacts including:[1]

- Coastal communities and ecosystems seeing more frequent and severe flooding
- Rising sea levels straining drainage and sewage systems, and intruding into groundwater aquifers
- Low-lying agricultural lands becoming too saline for cultivation

Dikes – Dikes in British Columbia are managed under the Dike Management Act, and are defined as an embankment, wall, fill piling, pump, gate, floodbox, and other types of construction or installation designed to prevent flooding of land. Dikes are managed either by a local diking authority or by the Province. Further information on dikes should be obtained from the local diking authority or the Province.[2]

Pesticide/Nutrient Runoff Management – Runoff occurs when land is over irrigated, or experiences heavy rainfall events, causing pesticides and nutrients in the soil to be washed away. Not only does pesticide and nutrient runoff have an impact on farming practices (requiring more applications of each), it can also have a significant and harmful impact off the farm, in-

1 gov.bc.ca/gov/content/environment/climate-change/adaptation/impacts

2 gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/dike-management

cluding eutrophication (an excess of nutrients leading to dense growth of plant life and death of animal life from lack of oxygen) of downstream water systems, death of aquatic species and impact to downstream farming. In addition, allowing discharge of nutrients and pesticides into local water bodies may contravene both provincial and federal regulations, and can result in fines or imprisonment.

Salt Wedge – A salt wedge is a saltwater intrusion into a body of freshwater as a wedge-shaped layer on the bottom of the freshwater. This occurs because saltwater is heavier than freshwater, and can move into the fresh body of water through tidal action.

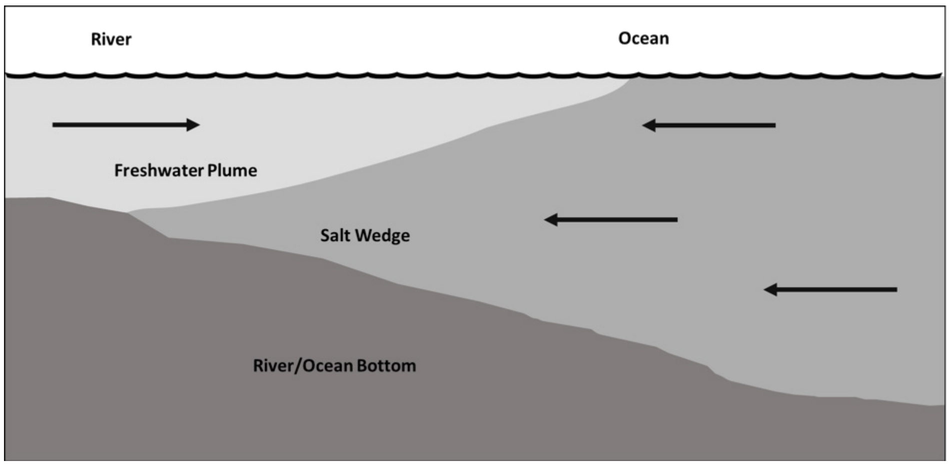



Figure 9: Salt Wedge

In B.C. this can be a significant issue due to the low velocity of some major rivers (e.g.the Fraser River, including both the north arm and the south arm; the Serpentine River; and the Nicomekl River) into the ocean delta, as the salt wedge can extend many kilometres inland. Water drawn from these sources can have high salt concentrations, impacting crop growth.

Saltwater Ingress/Intrusion – Occurs when saline water enters the fresh water system. In agriculture, this can occur in a number of ways, the most common of which are the following:

- Saline water intrusion into the groundwater aquifer. Typically, this occurs when too much groundwater is being extracted, and saline water from the nearby ocean moves into the local aquifer. Once this intrusion occurs, it can be very difficult to reverse the effects.
- Saline water intrusion into a local irrigation ditch system. Irrigation ditches are used by farmers to irrigate their crops; however, in some cases ditches are located next to a dike system. Salt water can enter the ditch system through the dike itself, or through a pipe/valve connecting ditch to ocean (to allow excess water to be discharged to the ocean).

Water Contamination – Water contamination can have significant impacts on farming activities, as contaminated water can sit on the crop leading to illness and death in those who handle or consume the vegetable/fruit. Contamination can occur from bacteria, parasites, viruses or chemicals. Typical contamination may include:

- Escherichia coli (E. coli)
- Salmonella
- Listeria monocytogenes
- Clostridium botulinum
- Norovirus
- Hepatitis
- Pesticides

# Notes:

Notes: