AGRICULTURE WATER DEMAND MODEL

Report for the Cowichan Valley Regional District

June 2013

BRITISH COLUMBIA

Canada

COVER PHOTO : Scott and Laurie Johnson, Toad Hollow Photography

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Authors

Ted van der Gulik, P.Eng.

Senior Engineer
B.C. Ministry of Agriculture
Sustainable Agriculture Management Branch
Abbotsford, BC

Denise Neilsen, Ph.D.

Research Scientist
Agriculture and Agri-Food Canada
Pacific Agri-Food Research Centre
Summerland, BC

Ron Fretwell

Program Developer
RHF Systems Ltd.
Kelowna, BC

Stephanie Tam, P.Eng.

Water Management Engineer
B.C. Ministry of Agriculture
Sustainable Agriculture Management Branch
Abbotsford, BC

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DISCLAIMER

The data that is presented in this report provides the best estimates for agriculture water demand that can be generated at this time. While every effort has been made to ensure the accuracy and completeness of the information, the information should not be considered as final. The Government of Canada, the BC Ministry of Agriculture, and the BC Agriculture Council or its directors, agents, employees, or contractors will not be liable for any claims, damages, or losses of any kind whatsoever arising out of the use of, or reliance upon, this information.

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Kelsey Lang	Ministry of Agriculture	Land Use Inventory
Michael Dykes	Ministry of Agriculture	Land Use Inventory
Wayne Haddow	Ministry of Agriculture	Land Use Inventory
Andrea Lawseth	Contractor	Land Use Survey

COVER PHOTO

The scenic photo of a farm nestled in a meadow in the Cowichan Valley of British Columbia, Canada was provided by Scott and Laurie Johnson of Toad Hollow Photography located in Duncan, BC.

The authors thank them for their gift of the beautiful photograph for our front cover.

IN-KIND CONTRIBUTION

The authors would like to express their gratitude to the Partnership of Water Sustainability of B.C. for their generous administration of funding for this project.

the partnership
for water sustainability in bc

Background

The Agriculture Water Demand Model (AWDM) was originally developed in the Okanagan Watershed. It was developed in response to rapid population growth, drought conditions from climate change, and the overall increased demand for water. Many of the watersheds in British Columbia (BC) are fully allocated or will be in the next 15 to 20 years. The AWDM helps to understand current agricultural water use and helps to fulfil the Province's commitment under the "*Living Water Smart – BC Water Plan*" to reserve water for agricultural lands. The Model can be used to establish agricultural water reserves throughout the various watersheds in BC by providing current and future agriculture water use data.

Climate change scenarios developed by the University of British Columbia (UBC) and the Pacific Agri-Food Research Centre (PARC) in Summerland predict an increase in agricultural water demand due to warmer and longer summers and lower precipitation during summer months in the future.

The Agriculture Water Demand Model was developed to provide current and future agricultural water demands. The Model calculates water use on a property-by-property basis, and sums each property to obtain a total water demand for the entire basin or each sub-basin. Crop, irrigation system type, soil texture and climate data are used to calculate the water demand. Climate data from 2003 was used to present information on one of the hottest and driest years on record and 1997 data was used to represent a wet year. Lands within the Agriculture Land Reserve (ALR), depicted in green in Figure 1 were included in the project.

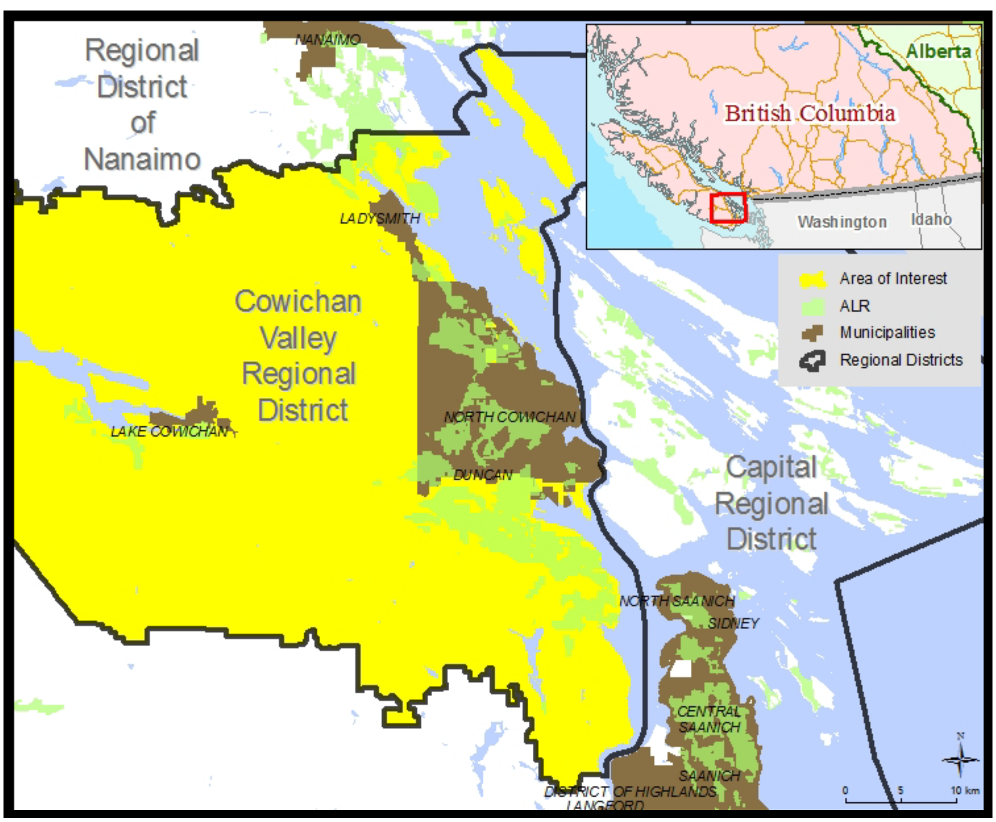

Figure 1 Map of ALR in Cowichan

Methodology

The Model is based on a Geographic Information System (GIS) database that contains information on cropping, irrigation system type, soil texture and climate data. An explanation of how information was compiled for each is given below. The survey area included all properties within the ALR and areas that were zoned for agriculture by the local government. The inventory was undertaken by Ministry of Agriculture (AGRI) staff, hired professional contractors and summer students.

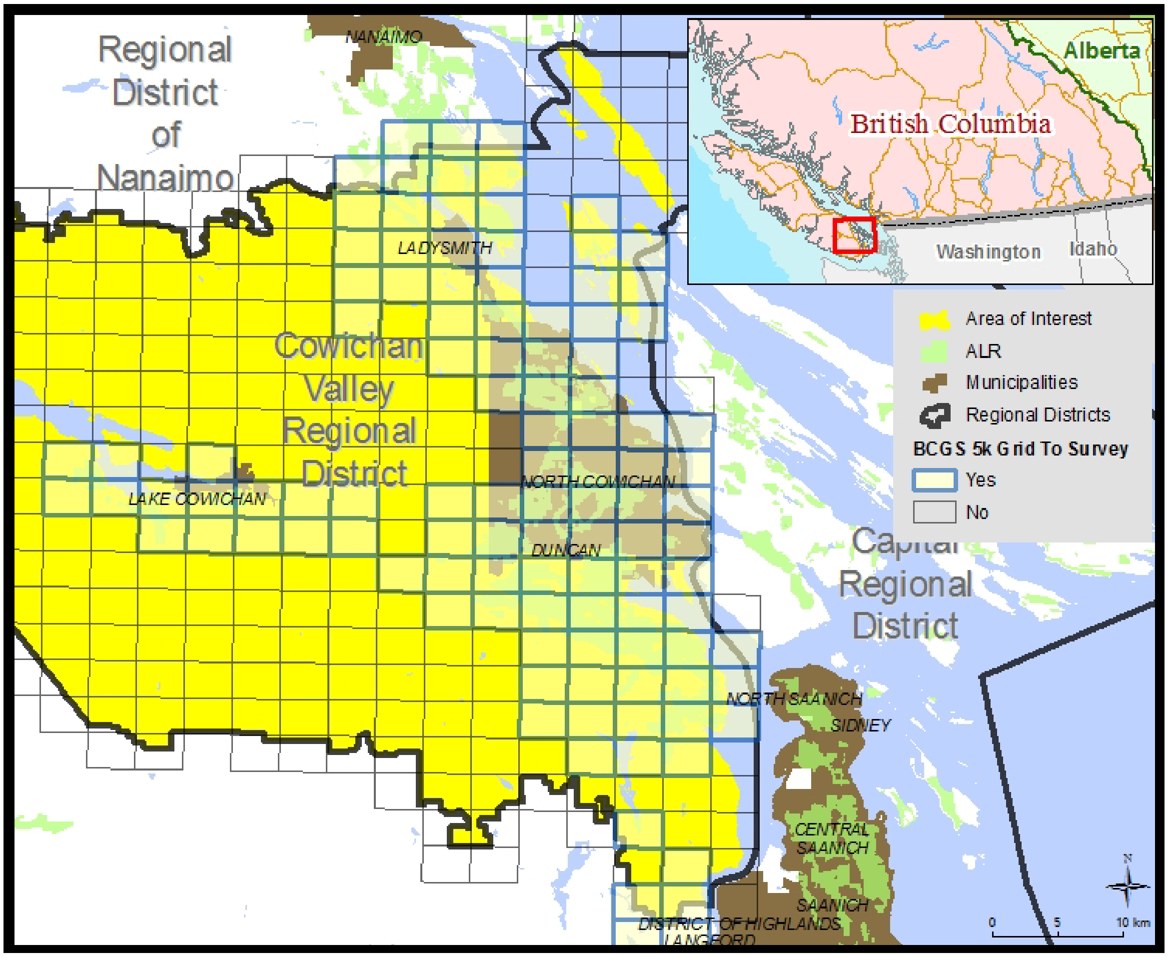

Figure 2 Overlaid Survey Map Sheets, Cowichan

Cadastre

Cadastre information was provided by Cowichan Valley Regional District. The entire watershed is covered in one dataset which allows the Model to report out on sub-basins and groundwater aquifers. A GIS technician used aerial photographs to conduct an initial review of cropping information by cadastre, and divided the cadastre into polygons that separate farmstead and driveways from cropping areas. Different crops were also separated into different polygons if the difference could be identified on the aerial photographs. This data was entered into the database that was used by the field teams to conduct and complete the land use survey.

Land Use Survey

The survey maps and database were created by AGRI for the survey crew to enter data about each property. Surveys were done during the summer of 2012. The survey crew drove by each property where the team checked the database for accuracy using visual observation and the aerial photographs on the survey maps. A Professional Agrologist verified what was on the site and a GIS technician altered the codes in the database as necessary (Figure 3). Corrections were handwritten on the maps. The map sheets were then brought back to the office to have the hand- drawn lines digitized into the GIS system and have the additional polygons entered into the database.

Once acquired through the survey, the land use data was brought into the GIS to facilitate analysis and produce maps. Digital data, in the form of a database and GIS shape files (for maps), is available upon request through a data sharing agreement with the Ministry of Agriculture.

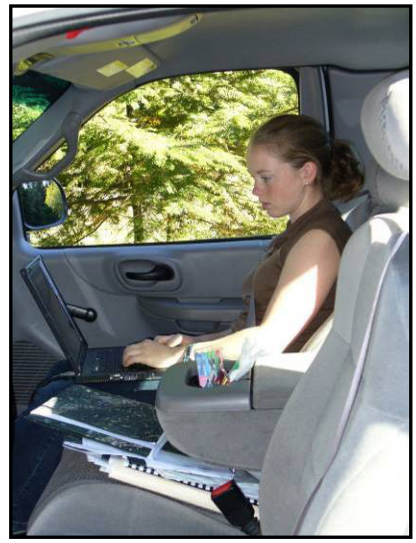

Figure 3 Land Use Survey

Figure 4 provides an example of a map sheet from the Cowichan watershed. The Cowichan region was divided into 82 map sheets. Each map sheet also had a key map to indicate where it was located in the region.

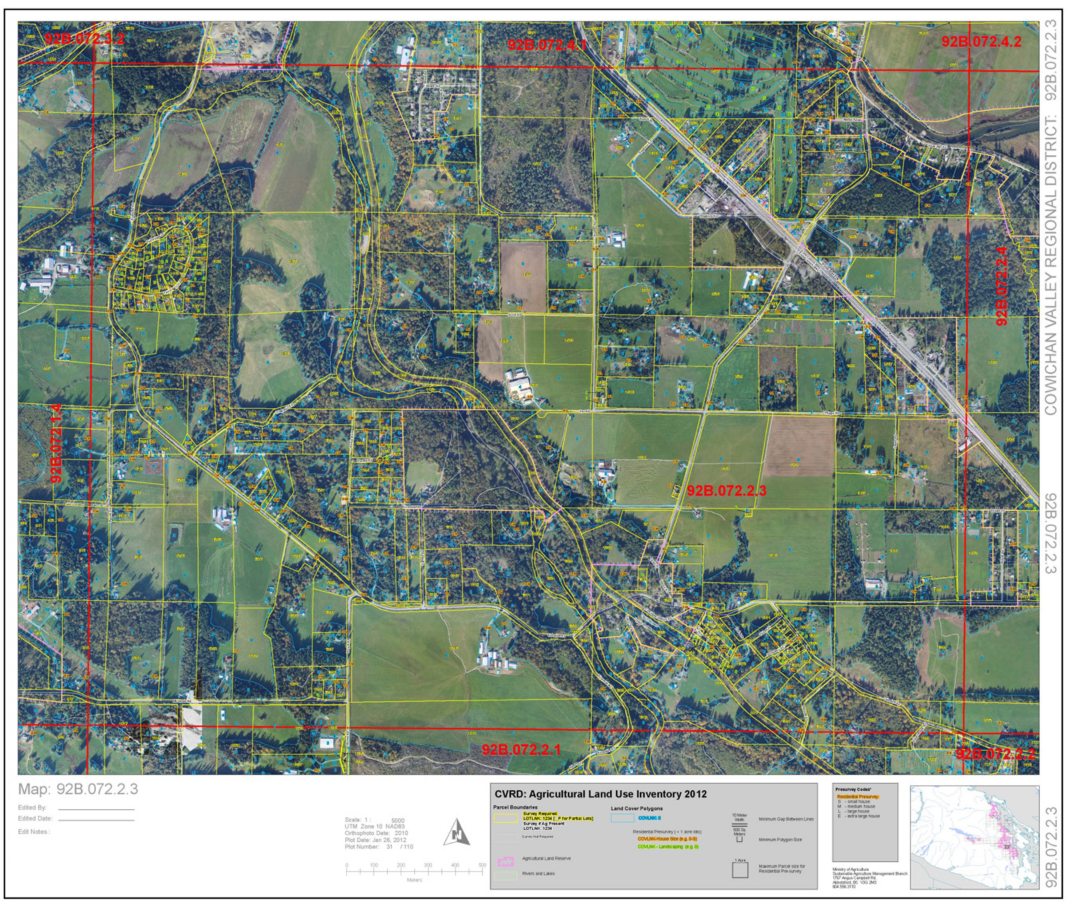

Figure 4 GIS Map Sheet

The smallest unit for which water use is calculated are the polygons within each cadastre. A polygon is determined by a change in land use or irrigation system within a cadastre. Polygons are designated as blue lines within each cadastre as shown in Figures 4 and 5. The dataset for Cowichan encompasses 4,356 inventoried land parcels that are in or partially in the ALR. There are a total of 18,734 polygons generated within these land parcels. Figure 5 provides an enhanced view of a cadastre containing three polygons. Each cadastre has a unique identifier as does each polygon. The polygon identifier is acknowledged by PolygonID. This allows the survey team to call up the cadastre in the database, review the number of polygons within the cadastre and ensure the land use is coded accurately for each polygon.

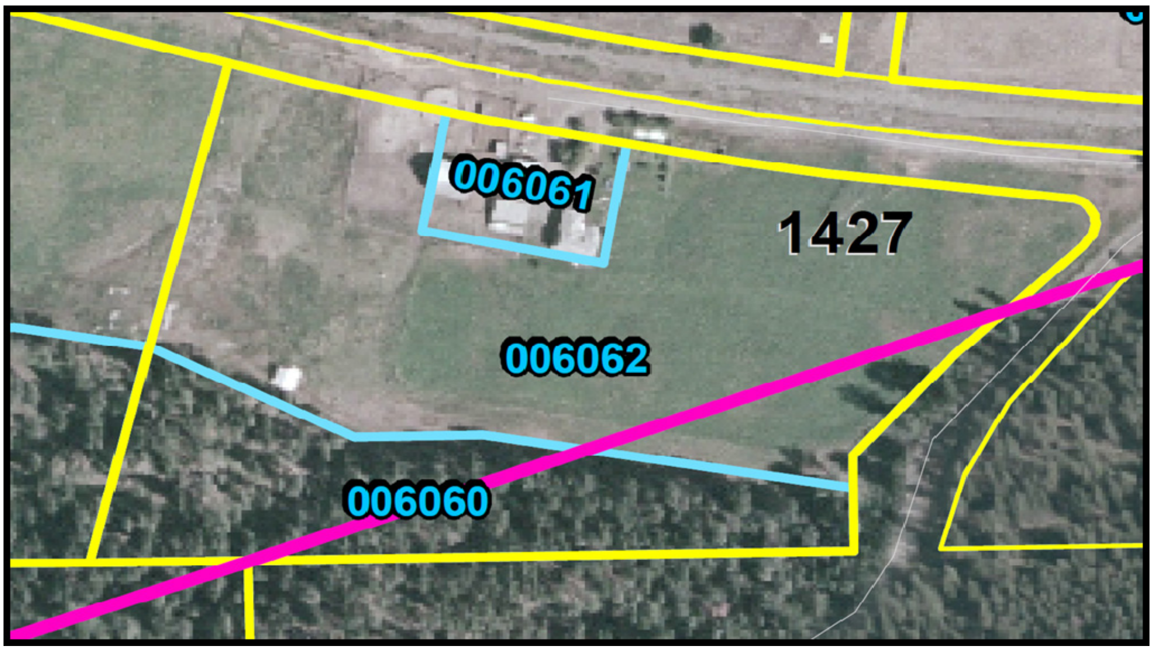

Figure 5 Cadastre with Polygons

Soil Information

Soil information was obtained digitally from the Ministry of Environment's Terrain and Soils Information System. The Computer Assisted Planning and Map Production application (CAPAMP) provided detailed (1:20,000 scale) soil surveys that were conducted in the Lower Mainland, on Southeast Vancouver Island, and in the Okanagan-Similkameen areas during the early 1980s. Products developed include soil survey reports, maps, agriculture capability and other related themes. Soil information required for this project was the soil texture (loam, etc.), the available water storage capacity and the peak infiltration rate for each texture type.

The intersection of soil boundaries with the cadastre and land use polygons creates additional polygons that the Model uses to calculate water demand. Figure 6 shows how the land use information is divided into additional polygons using the soil boundaries. The Model calculates water demand using every different combination of crop, soil and irrigation system as identified by each polygon.

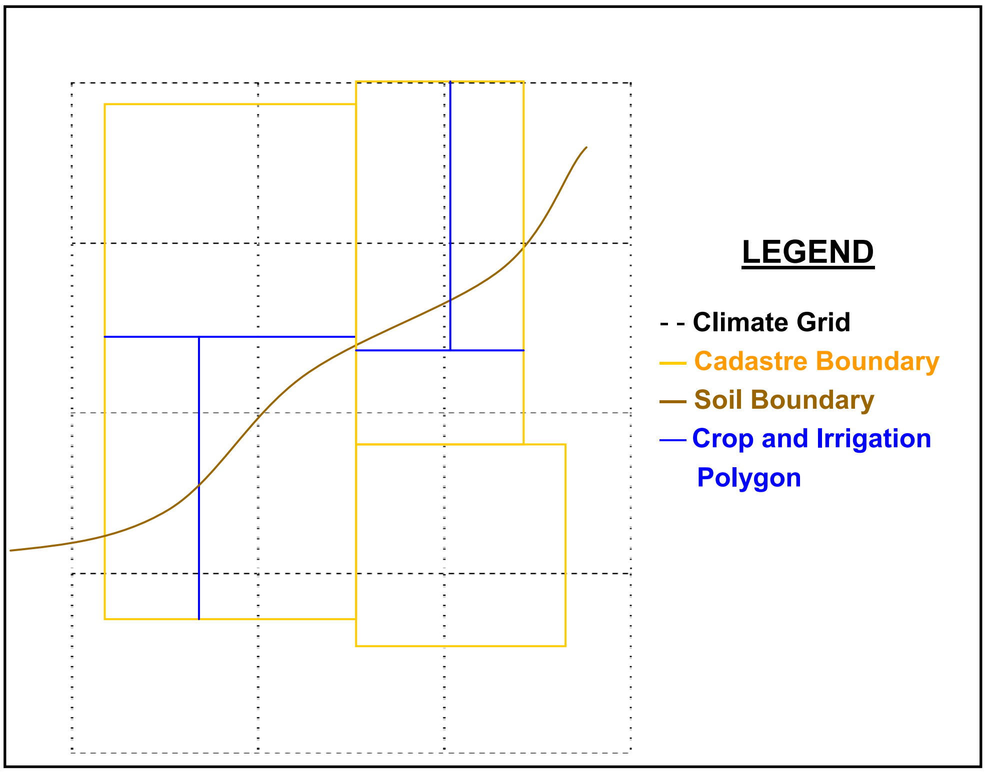

Figure 6 GIS Model Graphic

Climate Information

The agricultural water demand is calculated using climate, crop, irrigation system and soil information data. To incorporate the climatic diversity, climate layers were developed for the entire region on a 500 m x 500 m grid. Each grid cell contains daily climate data, minimum and maximum temperature (T_{min} and T_{max}), and precipitation which allows the Model to calculate a daily reference evapotranspiration rate (ET_o) value. A range of agro-climatic indices such as growing degree days (GDD), corn heat units (CHU), frost free days and temperature sum (Tsum) can also be calculated for each grid cell based on temperature data. These values are used to determine seeding dates and the length of the growing season in the Model.

The climate dataset has been developed by using existing data from climate stations in and around Cowichan Valley from 1961 to 2003. This climate data set was then interpolated to provide a climate data layer for the entire watershed on the 500 m x 500 m grid. A detailed description of the Model can be obtained by contacting the authors.

Some of the existing climate stations that were used to determine the climate coverage are shown in Figure 7. The attributes attached to each climate grid cell include:

- Latitude
- Longitude
- Elevation
- Aspect
- Slope
- Daily Precipitation
- Daily T_{max} and T_{min}

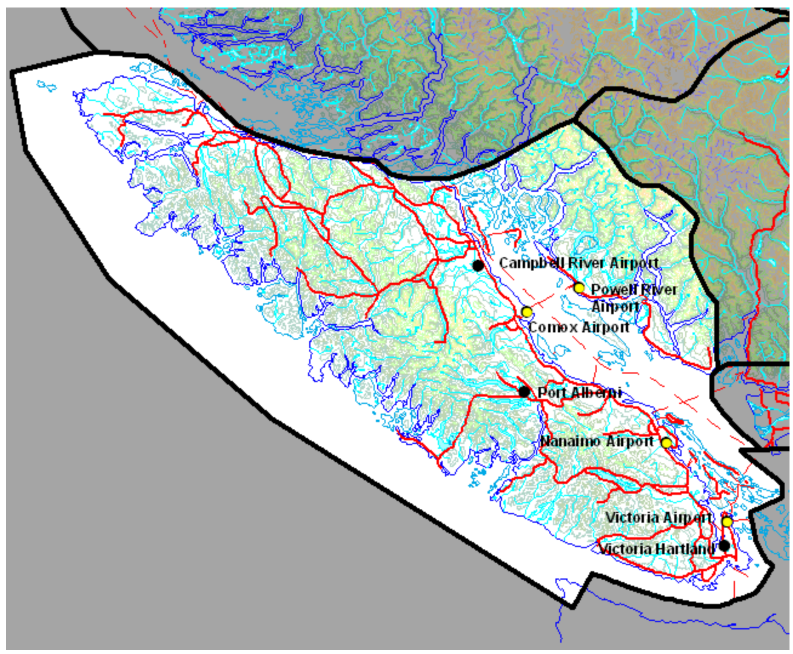

Figure 7 Cowichan Area Climate Stations

The climate database generated contains T_{min}, T_{max}, T_{mean} and Precipitation for each day of the year from 1961 to 2003. The parameters that need to be selected, calculated and stored within the Model are evapotranspiration (ET_o), Tsum of 1,000 (for the Island), effective precipitation (EP), frost free days, GDD with base temperatures of 5 ^oC and 10 ^oC, CHU, and first frost date. These climate and crop parameters are used to determine the growing season length as well as the beginning and end of the growing season in Julian day.

Model Calculations

The Model calculates the water demand for each polygon by using crop, irrigation, soil and climate parameters as explained below. Each polygon has been assigned an ID number as mentioned previously.

It should be noted that in for Southern Vancouver Island, many low-lying areas have high water tables which will reduce the overall irrigation demand. Agricultural water demand results from the Model will therefore be higher than what may actually be used as water tables have not been taken into the equation.

Crop

The CropID is an attribute of the PolygonID as each polygon will contain a single crop. The crop information (observed during the land use survey) has been collected and stored with PolygonID as part of the land use survey. CropID will provide cropping attributes to the Model for calculating water use for each polygon. CropID along with the climate data will also be used to calculate the growing season length and the beginning and end of the growing season. The attributes for CropID include rooting depth, availability coefficient, crop coefficient and a drip factor.

Rooting depth is the rooting depth for a mature crop in a deep soil.

An availability coefficient is assigned to each crop. The availability coefficient is used with the IrrigID to determine the soil moisture available to the crop for each PolygonID.

The crop coefficient adjusts the calculated ET_o for the stages of crop growth during the growing season. Crop coefficient curves have been developed for every crop. The crop coefficient curve allows the Model to calculate water demand with an adjusted daily ET_o value throughout the growing season.

The drip factor is used in the water use calculation for polygons where drip irrigation systems are used. Since the Model calculates water use by area, the drip factor adjusts the percentage of area irrigated by the drip system for that crop.

Irrigation

The IrrigID is an attribute of the PolygonID as each polygon will have a single irrigation system type operating. The irrigation information has been collected and stored (as observed during the land use survey) with the land use data. The land use survey determined if a polygon had an irrigation system operating, what the system type was, and if the system was being used. The IrrigID has an irrigation efficiency listed as an attribute.

Two of the IrrigID's, Overtreedrip and Overtreemicro are polygons that have two systems in place. Two irrigation ID's occur when an overhead irrigation system has been retained to provide crop cooling or frost protection. In this case, the efficiencies used in the Model are the drip and microsprinkler efficiencies.

Soil

The soil layer came from CAPAMP at the Ministry of Environment. In addition, soil data provided by Agriculture and Agri-Food Canada (AAFC) was also used to generate multiple soil layers within each polygon. Each parcel was assigned the most predominant soil polygon, and then for each crop field within that soil polygon, the most predominant texture within the crop's rooting depth was determined and assigned to the crop field.

Note that textures could repeat at different depths – the combined total of the thicknesses determined the most predominant texture. For example, a layer of 20 cm sand, followed by 40 cm clay and then 30 cm of sand would have sand be designated at the predominant soil texture.

The attributes attached to the SoilID is the Available Water Storage Capacity (AWSC) which is calculated using the soil texture and crop rooting depth.

The Maximum Soil Water Deficit (MSWD) is calculated to determine the parameters for the algorithm that is used to determine the Irrigation Requirement (IR). The Soil Moisture Deficit at the beginning of the season is calculated using the same terms as the MSWD.

Climate

The climate data in the Model is used to calculate a daily reference evapotranspiration rate (ET_o) for each climate grid cell. The data that is required to calculate this value are:

- Elevation, metres (m)
- Latitude, degrees (^{o})
- Minimum Temperature, degree Celsius (^oC)
- Maximum Temperature, degree Celsius (^oC)
- Classification as Coastal or Interior
- Classification as Arid or Humid
- Julian Day

Data that is assumed or are constants in this calculation are:

• Wind speed	2 m/s
• Albedo or canopy reflection coefficient,	0.23
• Solar constant, G_{sc}	0.082 $MJ^{-2}min^{-1}$
• Interior and Coastal coefficients, K_{Rs}	0.16 for interior locations 0.19 for coastal locations
• Humid and arid region coefficients, K_o	0 °C for humid/sub-humid climates 2 °C for arid/semi-arid climates

Agricultural Water Demand Equation

The Model calculates the Agriculture Water Demand (AWD) for each polygon, as a unique crop, irrigation system, soil and climate data is recorded on a polygon basis. The polygons are then summed to determine the AWD for each cadastre. The cadastre water demand values are then summed to determine AWD for the basin, sub-basin, water purveyor or local government. The following steps provide the process used by the Model to calculate Agricultural Water Demand. Detailed information is available on request.

1. *Pre-Season Soil Moisture Content*

Prior to the start of each crop's growing season, the soil's stored moisture content is modelled using the soil and crop evaporation and transpiration characteristics and the daily precipitation values. Precipitation increases the soil moisture content and evaporation (modelled using the reference potential evapotranspiration) depletes it. In general, during the pre-season, the soil moisture depth cannot be reduced beyond the maximum evaporation depth; grass crops in wet climates, however, can also remove moisture through crop transpiration.

The process used to model the pre-season soil moisture content is:

1. Determine whether the modelling area is considered to be in a *wet* or *dry* climate (see *Wet/Dry Climate Assessment*), and retrieve the early season evaporation factor in the modelling area
2. For each crop type, determine the start of the growing season (see *Growing Season Boundaries*)
3. For each crop and soil combination, determine the *maximum soil water deficit* (MSWD) and *maximum evaporation factor* (maxEvaporation)
4. Start the initial storedMoisture depth on January 1 at the MSWD level
5. For each day between the beginning of the calendar year and the crop's growing season start, calculate a new stored moisture from:

    a. the potential evapotranspiration (ET_o)
    b. the early season evaporation factor (earlyEvaporationFactor)
    c. the effective precipitation (EP) = actual precipitation x earlyEvaporationFactor
    d. daily Climate Moisture Deficit (CMD) = ET_o – EP
    e. storedMoisture = previous day's storedMoisture – CMD

A negative daily CMD (precipitation in excess of the day's potential evapotranspiration) adds to the stored moisture level while a positive climate moisture deficit reduces the amount in the stored moisture reservoir. The stored moisture cannot exceed the maximum soil moisture deficit; any precipitation that would take the stored moisture level above the MSWD gets ignored.

For all crops and conditions except for grass in wet climates, the stored moisture content cannot drop below the maximum soil water deficit minus the maximum evaporation depth; without any crop transpiration in play, only a certain amount of water can be removed from the soil through evaporative processes alone. Grass in wet climates does grow and remove moisture from the soil prior to the start of the irrigation season, however. In those cases, the stored moisture level can drop beyond the maximum evaporation depth, theoretically to 0.

Greenhouses and mushroom barns have no stored soil moisture content.

2. *In-Season Precipitation*

During the growing season, the amount of precipitation considered effective (EP) depends on the overall wetness of the modelling area's climate (see *Wet/Dry Climate Assessment*). In dry climates, the first 5 mm of precipitation is ignored, and the EP is calculated as 75% of remainder:

$$EP = (Precip - 5) \times 0.75$$

In wet climates, the first 5 mm is included in the EP. The EP is 75% of the actual precipitation:

$$EP = Precip \times 0.75$$

Greenhouses and mushroom barns automatically have an EP value of 0.

3. *Crop Cover Coefficient (K_c)*

As the crops grow, the amount of water they lose due to transpiration changes. Each crop has a pair of polynomial equations that provide the crop coefficient for any day during the crop's growing season. It was found that two curves, one for modelling time periods up to the present and one for extending the modelling into the future, provided a better sequence of crop coefficients than using a single curve for all years (currently 1961 to 2100). The application automatically selects the current or future curve as modelling moves across the c*rop Curve Changeover Year*.

For alfalfa crops, there are different sets of equations corresponding to different cuttings throughout the growing season.

4. *Crop Evapotranspiration (ET_c)*

The evapotranspiration for each crop is calculated as the general ET_o multiplied by the crop coefficient (K_c):

$$ET_c = ET_o \times K_c$$

5. *Climate Moisture Deficit (CMD)*

During the growing season, the daily Climate Moisture Deficit (CMD) is calculated as the crop evapotranspiration (ET_c) less the Effective Precipitation (EP):

$$CMD = ET_c – EP$$

During each crop's growing season, a stored moisture reservoir methodology is used that is similar to the soil moisture content calculation in the pre-season. On a daily basis, the stored moisture level is used towards satisfying the climate moisture deficit to produce an *adjusted Climate Moisture Deficit* (CMD_a):

$$CMD_a = CMD – storedMoisture$$

If the storedMoisture level exceeds the day's CMD, then the CMD_a is 0 and the stored moisture level is reduced by the CMD amount. If the CMD is greater than the stored moisture, then all of the stored moisture is used (storedMoisture is set to 0) and the adjusted CMD creates an irrigation requirement.

The upper limit for the storedMoisture level during the growing season is the maximum soil water deficit (MSWD) setting.

6. *Crop Water Requirement (CWR)*

The Crop Water Requirement is calculated as the adjusted Climate Moisture Deficit (CMD_a) multiplied by the soil water factor (swFactor) and any stress factor (used primarily for grass crops):

$$CWR = CMD_a \times swFactor \times stressFactor$$

7. *Irrigation Requirement (IR)*

The Irrigation Requirement is the Crop Water Requirement (CWR) after taking into account the irrigation efficiency (I_e) and, for drip systems, the drip factor (D_f):

$$IR = CWR \times \frac{D_f}{I_e}$$

For irrigation systems other than drip, the drip factor is 1.

8. *Irrigation Water Demand (IWDperc and IWD)*

The portion of the Irrigation Water Demand lost to deep percolation is the Irrigation Requirement (IR) multiplied by the percolation factor (soilPercFactor):

$$IWD_{perc} = IR \times soilPercFactor$$

The final Irrigation Water Demand (IWD) is then the Irrigation Requirement (IR) plus the loss to percolation (IWD_{perc}):

$$IWD = IR + IWD_{perc}$$

9. *Frost Protection*

For some crops (e.g. cranberries), an application of water is often used under certain climatic conditions to provide protection against frost damage. For cranberries, the rule is: when the temperature drops to 0 ^{o}C or below between March 16 and May 20 or between October 1 and November 15, a frost event will be calculated. The calculated value is an application of 2.5 mm per hour for 10 hours. In addition, 60% of the water is recirculated and reused, accounting for evaporation and seepage losses.

This amounts to a modelled water demand of 10 mm over the cranberry crop's area for each day that a frost event occurs between the specified dates.

10. *Annual Soil Moisture Deficit*

Prior to each crop's growing season, the Model calculates the soil's moisture content by starting it at full (maximum soil water deficit level) on January 1, and adjusting it daily according to precipitation and evaporation. During the growing season, simple evaporation is replaced by the crop's evapotranspiration as it progresses through its growth stages. At the completion of each crop's growing season, an annual soil moisture deficit (SMD) is calculated as the difference between the soil moisture content at that point and the maximum soil water deficit (MSWD):

$$SMD = MSWD - storedMoisture$$

In dry/cold climates, this amount represents water that the farmer would add to the soil in order to prevent it from freezing. Wet climates are assumed to have sufficient precipitation and warm enough temperatures to avoid the risk of freezing without this extra application of water; the SMD demand is therefore recorded only for dry areas.

There is no fixed date associated with irrigation to compensate for the annual soil moisture deficit. The farmer may choose to do it any time after the end of the growing season and before the freeze up. In the Model's summary reports, the water demand associated with the annual soil moisture deficit shows as occurring at time 0 (week 0, month 0, etc.) simply to differentiate it from other demands that do have a date of occurrence during the crop's growing season.

Greenhouses and mushroom barns do not have an annual soil moisture deficit.

11. Flood Harvesting

Cranberry crops are generally harvested using flood techniques. The Model calculates the flood harvesting demand as 250 mm of depth for 10% of the cranberry farmed area. For modelling purposes, it is assumed that 250 mm of water gets applied to the total cranberry crop area, 10% at a time. The water is reused for subsequent portions, but by the time the entire crop is harvested, all of the water is assumed to have been used and either depleted through losses or released from the farm.

The water demand is therefore calculated as a fixed 25 mm over the entire cranberry crop area. The harvesting generally takes place between mid-October and mid-November where the Model treats it as occurring on the fixed date of November 16.

Livestock Water Use

The Model calculates an estimated livestock water demand using agricultural census data and an estimate of the water use per animal. Water use for each animal type is calculated a bit differently depending on requirements. For example, for a dairy milking cow, the water demand for each animal includes, drinking, preparation for milking, pen and barn cleaning, milking system washout, bulk tank washout and milking parlor washing. However, for a dry dairy cow, the demand only includes drinking and pen and barn cleaning.

The water use is estimated on a daily basis per animal even though the facility is not cleaned daily. For example, for a broiler operation, the water use for cleaning a barn is calculated as 4 hours of pressure washing per cycle at a 10 gpm flow rate, multiplied by 6 cycles per barn with each barn holding 50,000 birds. On a daily basis, this is quite small with a value of 0.01 litres per day per bird applied.

For all cases, the daily livestock demand is applied to the farm location. However, in the case of beef, the livestock spend quite a bit of the year on the range. Since the actual location of the animals cannot be ascertained, the water demand is applied to the home farm location, even though most of the demand will not be from this location. Therefore, the animal water demand on a watershed scale will work fine but not when the demand is segregated into sub-watersheds or groundwater areas.

The estimates used for each livestock are shown in Table 1.

Table 1 Livestock Water Demand (Litres/day)

Animal Type	Drinking	Milking Preparation	Barn Component	Total
Milking Dairy Cow	65	5	15	85
Dry Cow	45		5	50
Swine	12		0.5	12.5
Poultry – Broiler	0.16		0.01	0.17
Poultry – Layer	0.08		0.01	0.09
Turkeys	0.35		0.01	0.36
Goats	8			8
Sheep	8			8
Beef – range, steer, bull, heifer	50			50
Horses	50			50

Definition and Calculation of Individual Terms used in the Irrigation Water Demand Equation

Growing Season Boundaries

There are three sets of considerations used in calculating the start and end of the irrigation season for each crop:

- temperature-based growing season derivations, generally using Temperature Sum (Tsum) or Growing Degree Day (GDD) accumulations
- the growing season overrides table
- the irrigation season overrides table

These form an order of precedence with later considerations potentially overriding the dates established for the previous rules. For example, the temperature-based rules might yield a growing season start date of day 90 for a given crop in a mild year. To avoid unrealistic irrigation starts, the season overrides table might enforce a minimum start day of 100 for that crop; at that point, the season start would be set to day 100. At the same time, a Water Purveyor might not turn on the water supply until day 105; specifying that as the minimum start day in the irrigation season overrides table would prevent any irrigation water demands until day 105.

This section describes the rules used to establish growing season boundaries based on the internal calculations of the Model. The GDD and Tsum Day calculations are described in separate sections. The *standard end of season* specified for several crops is the earlier of the end date of Growing Degree Day with base temperature of 5 ^{o}C (GDD_5) or the first frost.

1. ***Corn (silage corn)***
   - uses the corn_start date for the season start
   - season end: earlier of the killing frost or the day that the CHU2700 (2700 Corn Heat Units) threshold is reached

2. ***Sweetcorn, Potato, Tomato, Pepper, Strawberry, Vegetable, Pea***
   - corn_start date for the season start
   - corn start plus 110 days for the season end

3. ***Cereal***
   - GDD5 start for the season start
   - GDD5 start plus 130 days for the season end

4. ***AppleHD, AppleMD, AppleLD, Asparagus, Berry, Blueberry, Ginseng, Nuts, Raspberry, Sourcherry, Treefruit, Vineberry***
   - season start: (0.8447 x tsum600_day) + 18.877
   - standard end of season

5. ***Pumpkin***
   - corn_start date
   - standard end of season

6. Apricot

- season start: (0.9153 x tsum400_day) + 5.5809
- standard end of season

7. CherryHD, CherryMD, CherryLD

- season start: (0.7992 x tsum450_day) + 24.878
- standard end of season

8. Grape, Kiwi

- season start: (0.7992 x tsum450_day) + 24.878
- standard end of season

9. Peach, Nectarine

- season start: (0.8438 x tsum450_day) + 19.68
- standard end of season

10. Plum

- season start: (0.7982 x tsum500_day) + 25.417
- standard end of season

11. Pear

- season start: (0.8249 x tsum600_day) + 17.14
- standard end of season

12. Golf, TurfFarm

- season start: later of the GDD_5 start and the tsum300_day
- standard end of season

13. Domestic, Yard, TurfPark

- season start: later of the GDD_5 start and the tsum400_day
- standard end of season

14. Greenhouse (interior greenhouses)

- fixed season of April 1 – October 30

15. GH Tomato, GH Pepper, GH Cucumber

- fixed season of January 15 – November 30

16. GH Flower

- fixed season of March 1 – October 30

17. GH Nursery

- fixed season of April 1 – October 30

18. Mushroom

- all year: January 1 – December 31

19. Shrubs/Trees, Fstock, NurseryPOT

- season start: tsum500_day
- end: julian day 275

20. Floriculture

- season start: tsum500_day
- end: julian day 225

21. Cranberry

- season start: tsum500_day
- end: julian day 275

22. Grass, Forage, Alfalfa, Pasture

- season start: later of the GDD_5 and the tsum600_day
- standard end of season

23. Nursery

- season start: tsum400_day
- standard end of season

Evapotranspiration (ET_o)

The ET_o calculation follows the FAO Penman-Montieth equation. Two modifications were made to the equation:

- Step 6 – Inverse Relative Distance Earth-Sun (d_r)
  Instead of a fixed 365 days as a divisor, the actual number of days for each year (365 or 366) was used.

- Step 19 – Evapotranspiration (ET_o)
  For consistency, a temperature conversion factor of 273.16 was used instead of the rounded 273 listed.

Availability Coefficient (AC)

The availability coefficient is a factor representing the percentage of the soil's total water storage that the crop can readily extract. The factor is taken directly from the crop factors table (*crop_factors*) based on the cropId value.

Rooting Depth (RD)

The rooting depth represents the crop's maximum rooting depth and thus the depth of soil over which the plant interacts with the soil in terms of moisture extraction. The value is read directly from the crop factors table.

Stress Factor (stressFactor)

Some crops, such as *grasses*, are often irrigated to a less degree than their full theoretical requirement for optimal growth. The *stress factor* (*crop_groups_and_factors*) reduces the calculated demand for these crops.

Available Water Storage Capacity (AWSC)

The available water storage capacity is a factor representing the amount of water that a particular soil texture can hold without the water dropping through and being lost to deep percolation. The factor is taken directly from the soil factors table (*soil_factors*).

Maximum Soil Water Deficit (MSWD)

The maximum soil water deficit is the product of the crop's availability coefficient, rooting depth, and the available water storage capacity of the soil:

$$MSWD = RD \times AWSC \times AC$$

Deep Percolation Factor (soilPercFactor)

The soil percolation factor is used to calculate the amount of water lost to deep percolation under different management practices.

For greenhouse crops, the *greenhouse leaching factor* is used as the basic soil percolation factor. This is then multiplied by a greenhouse recirculation factor, if present, to reflect the percentage of water re-captured and re-used in greenhouse operations.

$$soilPercFactor = soilPercFactor \times (1 - recirculationFactor)$$

For Nursery Pot (Nursery POT) and Forestry Stock (Fstock) crops, the soil percolation factor is fixed at 35%. For other crops, the factor depends on the soil texture, the MSWD, the irrigation system, and the Irrigation Management Practices code. The percolation factors table (*soil_percolation_factors*) is read to find the first row with the correct management practices, soil texture and irrigation system, and a MSWD value that matches or exceeds the value calculated for the current land use polygon.

If the calculated MSWD value is greater than the index value for all rows in the percolation factors table, then the highest MSWD factor is used. If there is no match based on the passed parameters, then a default value of 0.25 is applied.

For example, a calculated MSWD value of 82.5 mm, a soil texture of sandy loam (SL) and an irrigation system of solid set overtree (Ssovertree) would retrieve the percolation factor associated with the MSWD index value of 75 mm in the current table (presently, there are rows for MSWD 50 mm and 75 mm for SL and Ssovertree).

Maximum Evaporation Factor (maxEvaporation)

Just as different soil textures can hold different amounts of water, they also have different depths that can be affected by evaporation. The factor is taken directly from the soil factors table.

Irrigation Efficiency (I_e)

Each irrigation system type has an associated efficiency factor (inefficient systems require the application of more water in order to satisfy the same crop water demand). The factor is read directly from the irrigation factors table (*irrigation_factors*).

Soil Water Factor (swFactor)

For the greenhouse "crop", the soil water factor is set to 1. For other crops, it is interpolated from a table (*soil_water_factors*) based on the MSWD. For Nurseries, the highest soil water factor (lowest MSWD index) in the table is used; otherwise, the two rows whose MSWD values bound the calculated MSWD are located and a soil water factor interpolated according to where the passed MSDW value lies between those bounds.

For example, using the current table with rows giving soil water factors of 0.95 and 0.9 for MSWD index values of 75 mm and 100 mm respectively, a calculated MSWD value of 82.5 mm would return a soil water factor of:

$$
\begin{aligned}
& 0.95 + \left[\frac{82.5 - 75}{100 - 75} \times \left(0.9 - 0.95\right) \right] \\
&= 0.935
\end{aligned}
$$

If the calculated MSWD value is higher or lower than the index values for all of the rows in the table, then the factor associated with the highest or lowest MSWD index is used.

Early Season Evaporation Factor (earlyEvaporationFactor)

The effective precipitation (precipitation that adds to the stored soil moisture content) can be different in the cooler pre-season than in the growing season. The early season evaporation factor is used to determine what percentage of the precipitation is considered effective prior to the growing season.

Crop Coefficient (K_c)

The crop coefficient is calculated from a set of fourth degree polynomial equations representing the crop's ground coverage throughout its growing season. The coefficients for each term are read from the crop factors table based on the crop type, with the variable equalling the number of days since the start of the crop's growing season. For example, the crop coefficient for Grape on day 35 of the growing season would be calculated as:

$$
\begin{aligned}
K_c &= [0.0000000031 \times (35)^4] + [-0.0000013775 \times (35)^3] + (0.0001634536 \times (35)^2] + (-0.0011179845 \times 35) + 0.2399004137 \\
&= 0.346593241
\end{aligned}
$$

Alfalfa crops have an additional consideration. More than one cutting of alfalfa can be harvested over the course of the growing season, and the terms used for the crop coefficient equation changes for the different cuttings. For alfalfa, the alfalfa cuttings table is first used to determine which cutting period the day belongs to (first, intermediate or last), and after that the associated record in the crop factors table is accessed to determine the terms.

There are two sets of polynomial coefficients used to calculate the crop coefficient; the first set is used for modelling time periods up to the year specified as the *crop curve changeover year*; and the second for modelling into the future. The changeover year will be modified as time goes on and new historical climate observations become available.

Growing Degree Days (GDD)

The Growing Degree Day calculations generate the start and end of GDD accumulation.

1. ***Start of GDD Accumulation***

   For each base temperature (bases 5 and 10 are always calculated, other base temperature can be derived), the start of the accumulation is defined as occurring after 5 consecutive days of T_{mean} matching or exceeding the base temperature (BaseT). The search for the start day gets reset if a killing frost (< –2 ^{o}C) occurs, even after the accumulation has started. The search also restarts if there are 2 or more consecutive days of $T_{min} \leq 0$ ^{o}C. The GDD start is limited to Julian days 1 to 210; if the accumulation has not started by that point, then it is unlikely to produce a reasonable starting point for any crop.

2. ***End of GDD accumulation***

   The search for the end of the GDD accumulation begins 50 days after its start. The accumulation ends on the earlier of 5 consecutive days where T_{mean} fails to reach BaseT (strictly <u>*less than*</u>) or the first killing frost (–2 ^{o}C).

During the GDD accumulation period, the daily contribution is the difference between T_{mean} and BaseT, as long as T_{mean} is not less than BaseT:

$$GDD = T_{mean} - BaseT; \text{ 0 if negative}$$

Frost Indices

Three frost indices are tracked for each year:

- the last spring frost is the latest day in the first 180 days of the year with a $T_{min} \leq 0$ ^{o}C
- the first fall frost is the first day between days 240 and the end of the year where $T_{min} \leq 0$ ^{o}C
- the killing frost is the first day on or after the first fall frost where $T_{min} \leq -2$ ^{o}C

Corn Heat Units (CHU)

The Corn Heat Unit is the average of two terms using T_{min} and T_{max}. Prior to averaging, each term is set to 0 individually if it is negative.

$$\text{term1} = [3.33 \times (T_{max} - 10)] - [0.084 \times (T_{max} - 10) \times (T_{max} - 10)];\ 0 \text{ if negative}$$

$$\text{term2} = 1.8 \times (T_{min} - 4.44);\ 0 \text{ if negative}$$

$$\text{CHU} = \frac{(\text{term1} + \text{term2})}{2}$$

Corn Season Start and End

The corn season boundary derivations are similar to the GDD determinations. The start day is established by 3 consecutive days where $T_{mean} \geq 11.2\ ^{o}C$. As in the case of the GDD calculations, the search for the corn season start day gets reset if $T_{min} \leq -2\ ^{o}C$, or if there are 2 or more consecutive days of $-2\ ^{o}C \leq T_{min} \leq 0\ ^{o}C$.

The search for the silage corn season end begins 50 days after the start. The season ends on the earlier of a mean temperature dropping below 10.1 or a killing frost.

The end of the sweet corn season is defined as 110 days after the season start.

Tsum Indices

The Tsum day for a given number is defined as the day that the sum of the positive daily T_{mean} reaches that number. For example, the Tsum400 day is the day where the sum of the positive T_{mean} starting on January 1 sum to 400 units or greater.

Days where T_{mean} falls below 0 ^{o}C are simply not counted; therefore, the Model does not restart the accumulation sequence.

Wet/Dry Climate Assessment

Starting with the Lower Mainland, some of the modelling calculations depend on an assessment of the general climatic environment as *wet* or *dry*. For example, when modelling the soil moisture content prior to the start of the crop's growing season, the reservoir can only be drawn down by evaporation except for *grass* crops in *wet* climates which can pull additional moisture out of the soil.

The assessment of wet or dry uses the total precipitation between May 1 and September 30. If the total is more than 125 mm during that period, the climate is considered to be *wet* and otherwise *dry*.

Groundwater Use

The Model generates water sources for irrigation systems. This is done by first determining which farms are supplied by a water purveyor, and then coding those farms as such. Most water purveyors use surface water but where groundwater is used, the farms are coded as groundwater use. The second step is to check all water licences and assign the water licences to properties in the database. The remaining farms that are irrigating will therefore not have a water licence or be supplied by a water purveyor. The assumption is made that these farms are irrigated by groundwater sources.

Land Use Results

A summary of the land area and the inventoried area of the Cowichan Valley Regional District is shown in Table 2. The inventoried area includes parcels that are in and partially in the Agricultural Land Reserve (ALR). The primary agricultural use of the ARL area is shown in Table 3 where only 1,795 parcels currently have active agriculture. Refer to the Agricultural Land Use Inventory reports for details.

The Model also reports out on groundwater aquifers. Figure 8 provides a schematic of the higher yielding aquifer areas in the Cowichan Region based on the information from B.C. Ministry of Environment.

Table 2 Overview of CVRD's Land and Inventoried Area

Area Type	Area (ha)	Number of Parcels
CVRD		
Total Area	426,422	-
Area of Water Feature	82,441	-
Area of Land (excluding water features)	343,981	-
ALR Area	19,053	4,987
Area of First Nations Reserve	6,500	348
Inventoried Area		
Total Inventoried Area	28,805	4,356
Area of First Nations Reserve in ALR	2,090	238

Table 3 Summary of Primary Agricultural Activities within the Inventoried Area where Primary Land Use is Agriculture in CVRD		
Primary Agriculture Activity	**Total Land Cover (ha)**	**Number of Parcels**
Glass and poly greenhouse	2	13
Grains, cereals, oilseeds	34	9
Tree fruits	11	15
Grapes	108	32
Berries	39	14
Forage	6,092	1,631
Vegetables	25	29
Floriculture	1	4
Turf, Nut Trees, Specialty	19	5
Nursery	76	37
Cultivated land, crop in transition	22	6
Total	**6,431**	**1,795**

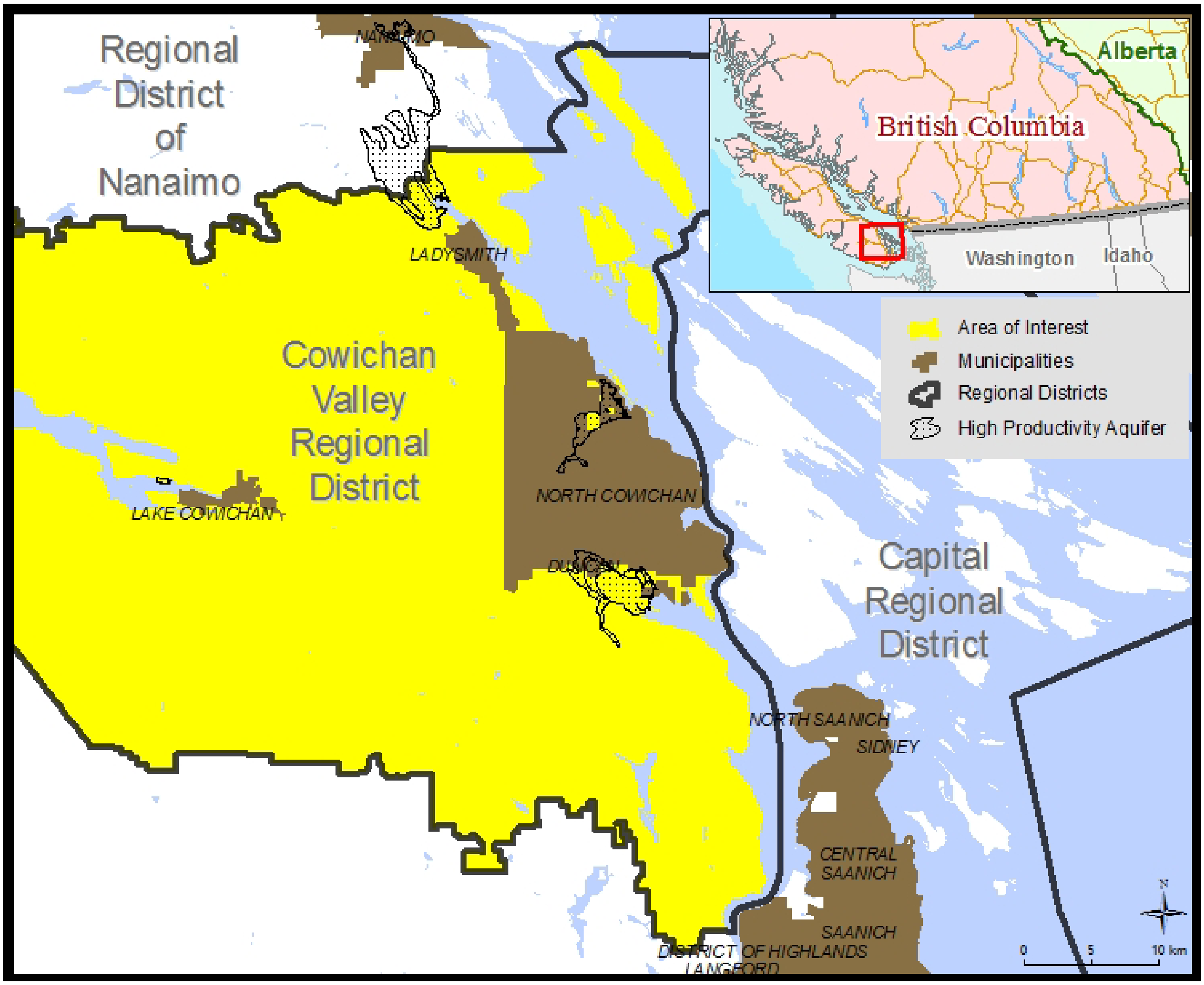

Figure 8 Higher Productive Groundwater Aquifers in Cowichan Valley

Agricultural Water Demand Model Results

The Model has a reporting feature that can save and generate reports for many different scenarios that have been pre-developed. This report will provide a summary of the reported data in the Appendices. Climate data from 1997 and 2003 were chosen as they represent a relatively wet year and dry year respectively. Most reports are based on the 2003 data since the maximum current demand can then be presented.

Annual Crop Water Demand – Tables A and B

The Model can use three different irrigation management factors, good, average and poor. Unless otherwise noted, average management were used in the tables. Table A provides the annual irrigation water demand for current crop and irrigation systems for the year 2003 using average irrigation management, and Table B provides the same data for 1997.

The outdoor irrigated acreage in Cowichan is 2,503 hectares (ha) including 73 ha in golf courses. The total annual irrigation demand for this area was 18,531,206 m^3 in 2003 (a dry year), and dropped to 7,528,548 m^3 in 1997 (a wet year).

Of interest is that during a wet year like 1997, the demand was only 40% of a hot dry year like 2003. Another point to consider is that the actual water demand supplied by an irrigation system may be less than the numbers shown above. The reason is that the Model does not have an adjustment for water supplied to the crop by high water tables. In portions of the Cowichan, agriculture is located in the lowland regions which have predominantly high water tables due to the drainage and irrigation ditch infrastructure. The high water tables will reduce irrigation demand that is not accounted for in the Model outputs. The numbers should therefore be considered the highest estimate demand.

In addition, the Model also calculates demand based on relatively good practices. As such, actual use may actually be higher or lower than what is calculated by the Model.

The predominant irrigated agriculture crop in the Cowichan is forage that includes forage corn, grass, legume and pasture. Significantly less are grapes and berry crops.

Annual Water Demand Reported by Irrigation System – Table C

The crop irrigation demand can also be reported by irrigation system type as shown in Tables C. The total area irrigated includes indoor irrigation, such as greenhouses. The predominant irrigation system used is travelling guns followed by sprinkler systems.

Annual Water Demand by Soil Texture – Table D

Table D provides the annual water demand by soil texture. Where soil texture data is missing, the soil texture has been defaulted to sandy loam. The defaults are shown in Table D.

Annual Water Demand by Aquifer – Table E

The Model can estimate water demand based on aquifer boundaries. Some properties are located outside of known aquifers; therefore, were listed under "others".

Irrigation Management Factors – Table F

The Model can estimate water demand based on poor, average and good irrigation management factors. This is accomplished by developing an irrigation management factor for each crop, soil and irrigation system combination based on subjective decision and percolation rates. The Maximum Soil Water Deficit (MSWD) is the maximum amount of water that can be stored in the soil within the crop rooting zone. An irrigation system applying more water than what can be stored will result in percolation beyond the crop's rooting depth. Irrigation systems with high application rates will have a probability of higher percolation rates, a stationary gun for instance.

For each soil class, a range of four MSWD are provided, which reflect a range of crop rooting depths. An irrigation management factor, which determines the amount of leaching, is established for each of the MSWD values for the soil types (Table 4). The management factor is based on irrigation expertise as to how the various irrigation systems are able to operate. For example, Table 4 indicates that for a loam soil and a MSWD of 38 mm, a solid set overtree system has a management factor of 0.1 for good management while the drip system has a management factor of 0.05. This indicates that it is easier to prevent percolation with a drip system than it is with a solid set sprinkler system. For poor management, the factors are higher.

There are a total of 1,344 irrigation management factors established for the 16 different soil textures, MSWD and 21 different irrigation system combinations used in the Model.

Table 4 Irrigation Management Factors

Soil Texture	MSWD	Solid Set Overtree			Drip		
		Good	Average	Poor	Good	Average	Poor
Loam	38	0.10	0.15	0.20	0.05	0.10	0.15
	50	0.05	0.10	0.15	0.05	0.075	0.10
	75	0.05	0.10	0.15	0.05	0.075	0.10
	100	0.05	0.075	0.10	0.05	0.075	0.10
Sandy loam	25	0.20	0.225	0.25	0.10	0.15	0.20
	38	0.10	0.15	0.20	0.10	0.125	0.15
	50	0.05	0.10	0.15	0.05	0.10	0.10
	75	0.05	0.10	0.15	0.05	0.075	0.10

The management factors increase as the MSWD decreases because there is less soil storage potential in the crop rooting depth. For irrigation systems such as guns, operating on a pasture which has a shallow rooting depth, on a sandy soil which cannot store much water, the poor irrigation management factor may be as high as 0.5.

The management factor used in the Model assumes all losses are deep percolation while it is likely that some losses will occur as runoff as well.

Table F provides an overview of the impacts on the management factor and irrigation systems used. Since the predominant crop type is forage and the type of irrigation systems are sprinkler or gun systems there is not much difference in water demand shown for improving irrigation management.

Table F also provides percolation rates based on good, average and poor management using 2003 climate data. In summary, good management is 1,118,818 m^3, average is 1,483,769 m^3 and poor management is 1,848,720 m^3. Percolation rates for poor management are 65% higher than for good management.

Deep Percolation – Table G

The percolation rates vary by crop, irrigation system type, soil and the management factor used. Table G shows the deep percolation amounts by irrigation system type for average management. The last column provides a good indication of the average percolation per hectare for the various irrigation system types. Landscape sprinkler systems have a high percolation rate predominantly because application rates are high and the crop rooting depth is quite shallow. Microspray and microsprinklers are also shown to have high percolation rates but these systems are likely inside greenhouse nursery systems and the water may be recirculated

Improved Irrigation Efficiency and good Management – Table H

There is an opportunity to reduce water use by converting irrigation systems to a higher efficiency for some crops. For example, drip systems could be used for all berry crops, vegetable crops and some of the other horticultural crops, but not forage crops. In addition, using better management such as irrigation scheduling techniques will also reduce water use, especially on forage where drip conversion is not possible. Table H provides a scenario of water demand if all sprinkler systems are converted to drip systems for horticultural crops in Cowichan, using good irrigation management. The water demand for 2003 would reduce from 18,531,206 m^3 to 17,670,753 m^3 if sprinkler systems were converted to drip and good management practices were implemented. Since forage is such a predominant crop in the region, the amount of reduction achieved is quite small.

Livestock Water Use – Table I

The Model provides an estimate of water use for livestock. The estimate is based on the number of animals in Cowichan as determined by the latest census, the drinking water required for each animal per day and the barn or milking parlour wash water. Values used are shown in Table I. For Cowichan, the amount of livestock water is estimated at 248,278 m^3.

Climate Change Water Demand for 2050 – Table J

The Model also has access to climate change information until the year 2100. While data can be run for each year, three driest years in the 2050's were selected to give a representation of climate change.

Figure 9 shows the climate data results which indicate that 2053, 2056, and 2059 generate the highest annual ET_o and lowest annual precipitation. These three years were used in this report.

Table J provides the results of climate change on irrigation demand for the three years selected using current crops and irrigation systems. Current crops and irrigation systems are used to show the increase due to climate change only, with no other changes taking place.

The three climate change scenarios used in this report are RCP26, RCP45 and RCP85. While the data is shown from each Model for all three years, it is best to average the results from each Model. Without running a lot of climate datasets it is difficult to get a reliable trend.

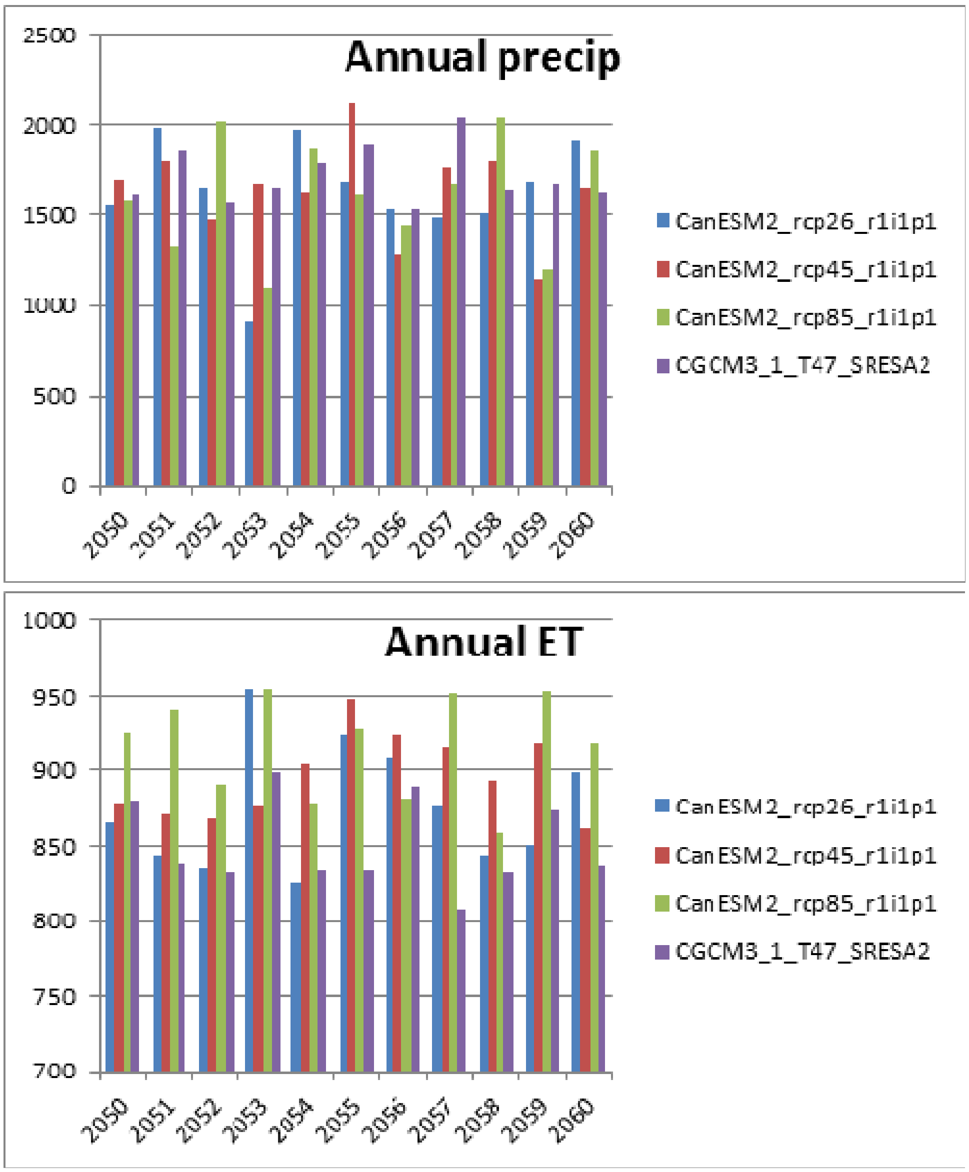

Figure 9 Annual ET and Effective Precipitation in 2050's

However, the preliminary data indicates that without changing crops and irrigation systems climate change may have a significant impact in drier years. On average, the three climate model results for the three hottest and driest years in the 2050's do not show much of an increase due to climate change.

However, RCP85 and RCP26 generate an increase of 22% for specific year in the 2050's. To get a better picture of the effects of climate change the Model should be run with all of the climate change models for all years. This will generate more data points to get an idea of the climate change trend.

Figure 10 shows all of the climate change scenario runs for the Okanagan using 12 climate models from 1960 to 2100. This work was compiled by Denise Neilsen at the Agriculture and Agri-Food Canada – Summerland Research Station. There is a lot of scatter in this figure, but it is obvious that there is a trend of increasing water demand.

The three climate change models used in this report are RCP26, RCP45 and RCP85. Running only three climate change models on three selected future years in RDN is not sufficient to provide a trend like in Figure 10. What the results do show is that in an extreme climate scenario, it is possible to have an annual water demand that is 30% higher than what was experienced in 2003. Averaging the data between the three climate change models shows that if the data for just the year 2053 is examined, the increase in demand is 10% higher than 2003. More runs of the climate change models will be required to better estimate a climate change trend for RDN.

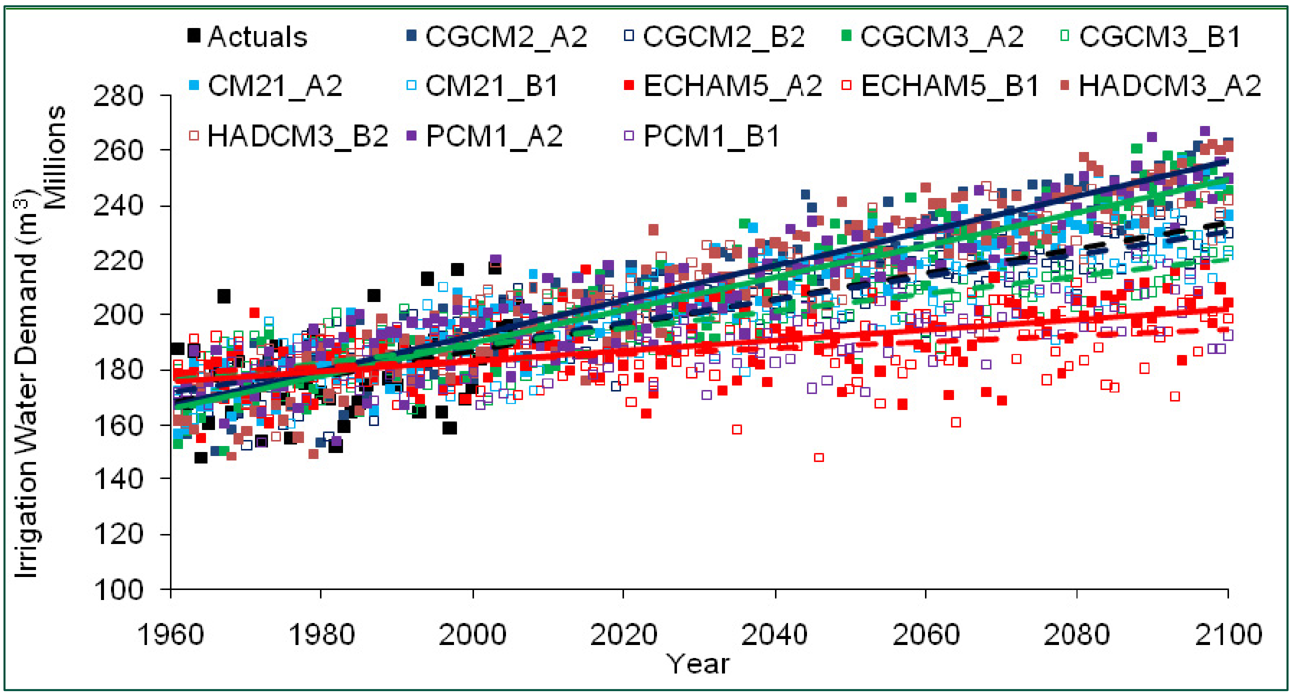

Figure 10 **Future Irrigation Demand for All Outdoor Uses in the Okanagan in Response to Observed Climate Data (Actuals) and Future Climate Data Projected from a Range of Global Climate Models**

Agricultural Buildout Crop Water Demand Using 2003 Climate Data – Table K

An agricultural buildout scenario was developed that looked at potential agricultural lands that could be irrigated in the future. The rules used to establish where potential additional agricultural lands were located in Cowichan Valley are as follows:

- within 1,000 m of water supply (lake)
- within 1,000 m of water supply (water course)
- within 1,000 m of water supply (wetland)
- within 1,000 m of high productivity aquifer

- within 1,000 m of water purveyor
- with Ag Capability class 1-4 only where available
- must be within the ALR
- below 250 m average elevation

For the areas that are determined to be eligible for future buildout, a crop and irrigation system need to be applied. Where a crop already existed in the land use inventory, that crop would remain and an irrigation system assigned. If no crop existed, then a crop and irrigation system are assigned as per the criteria below.

- **Forage crops**: 50% of buildout area with sprinkler irrigation
- **Pasture**: 10% of buildout area with sprinkler irrigation
- **Grapes**: 20% of buildout area with drip irrigation
- **Vegetables**: 20% of buildout area with drip irrigation

Figure 11 indicates the location of agricultural land that is currently irrigated (dark green) and the land that can be potentially irrigated (red). Based on the scenario provided for Cowichan, the additional agricultural land that could be irrigated is 4,417 ha. The water demand for a year like 2003 would be 43,654,055 m^3 assuming efficient irrigation systems and good management.

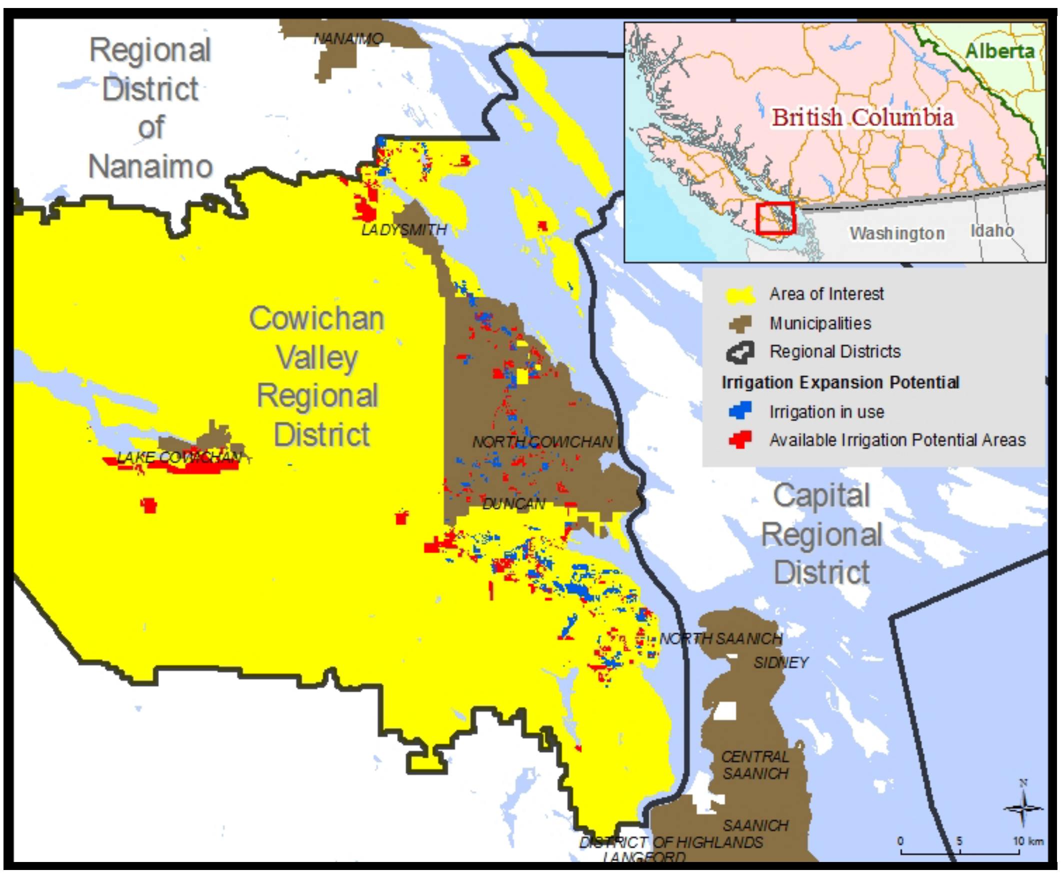

Figure 11 Cowichan Irrigation Expansion Potential

Agricultural Buildout Crop Water Demand for 2050 – Table L

The same irrigation expansion and cropping scenario used to generate the values in Table K were used to generate the climate change water demand shown in Table L. Three climate models were used and the results averaged. When climate change is added to the buildout scenario the water demand increases could increase to 53,748,201 m^3 for RCP26 in 2053. Again more runs are required to develop a good trend with the climate change data. See discussion under Table J.

Irrigation Systems Used for the Buildout Scenario – Table M

Table M provides an account of the irrigation systems used by area for the buildout scenario in Table K. It takes into account the irrigation systems that were assigned in the buildout scenarios used.

Aquifer Water Demand for the Buildout Scenario – Table N

Table N provides an account of the water demand based on aquifer for the buildout scenario in Table K. It can be compared with the values in Table E without buildout.

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Appendix Tables

Appendix Table A 2003 Water Demand by Crop with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Crop Group	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Apple	2.9	18,761	640	-	-	-	8.7	56,197	644	11.7	**74,959**	643
Berry	10.2	94,134	922	-	-	-	25.7	217,268	846	35.9	**311,402**	868
Blueberry	0.6	1,947	353	-	-	-	5.7	28,361	502	6.2	**30,309**	488
Cherry	-	-	-	-	-	-	0.1	863	611	0.1	**863**	611
Forage	1,457.0	11,250,821	772	-	-	-	686.7	5,184,093	755	2,143.7	**16,434,913**	767
Fruit	-	-	-	-	-	-	0.7	3,520	524	0.7	**3,520**	524
Golf	49.2	369,537	751	-	-	-	23.7	184,060	775	73.0	**553,597**	759
Grape	30.6	80,028	262	-	-	-	82.5	216,850	263	113.1	**296,878**	262
Greenhouse	1.2	22,045	1,905	-	-	-	5.1	96,375	1,897	6.2	**118,419**	1,898
Nursery Floriculture	-	-	-	-	-	-	2.3	10,079	433	2.3	**10,079**	433
Nursery Shrubs/Trees	3.5	18,349	518	-	-	-	5.4	33,367	613	9.0	**51,716**	576
Pasture/Grass	8.3	58,108	701	-	-	-	13.9	101,410	729	22.2	**159,518**	719
Raspberry	1.7	11,663	705	-	-	-	2.4	10,450	444	4.0	**22,113**	552
Recreational Turf	1.6	12,240	775	-	-	-	14.3	110,386	771	15.9	**122,626**	772
Strawberry	1.8	10,870	604	-	-	-	0.6	2,070	341	2.4	**12,941**	538
Sweetcorn	5.9	24,391	415	-	-	-	0.2	1,067	456	6.1	**25,458**	417
Turf Farm	1.7	12,111	718	-	-	-	-	-	-	1.7	**12,111**	718
Vegetable	16.9	98,455	583	-	-	-	32.5	191,328	589	49.4	**289,783**	587
TOTALS	1,593.0	12,083,460	759	-	-	-	910.6	6,447,746	708	2,503.6	**18,531,206**	740

Appendix Table B 1997 Water Demand by Crop with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Crop Group	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Apple	2.9	8,253	282	-	-	-	8.7	21,816.0	250.0	11.7	**30,069**	258
Berry	10.2	23,738	232	-	-	-	25.7	66,000	257	35.9	**89,738**	250
Blueberry	0.6	709	128	-	-	-	5.7	9,800	173	6.2	**10,509**	169
Cherry	-	-	-	-	-	-	0.1	358	254	0.1	**358**	254
Forage	1,457.0	4,572,532	314	-	-	-	686.7	2,054,393	299	2,143.7	**6,626,924**	309
Fruit	-	-	-	-	-	-	0.7	900	134	0.7	**900**	134
Golf	49.2	203,829	414	-	-	-	23.7	98,261	414	73.0	**302,089**	414
Grape	30.6	11,938	39	-	-	-	82.5	34,996	42	113.1	**46,934**	41
Greenhouse	1.2	20,197	1,745	-	-	-	5.1	88,509	1,742	6.2	**108,706**	1,742
Nursery Floriculture	-	-	-	-	-	-	2.3	3,987	171	2.3	**3,987**	171
Nursery Shrubs/Trees	3.5	5,800	164	-	-	-	5.4	10,264	189	9.0	**16,064**	179
Pasture/Grass	8.3	27,131	327	-	-	-	13.9	46,706	336	22.2	**73,837**	333
Raspberry	1.7	3,769	228	-	-	-	2.4	2,890	123	4.0	**6,659**	166
Recreational Turf	1.6	6,037	382	-	-	-	14.3	54,388	380	15.9	**60,425**	380
Strawberry	1.8	5,140	286	-	-	-	0.6	954	157	2.4	**6,094**	253
Sweetcorn	5.9	5,815	99	-	-	-	0.2	331	141	6.1	**6,146**	101
Turf Farm	1.7	6,016	357	-	-	-	-	-	-	1.7	**6,016**	357
Vegetable	16.9	45,535	270	-	-	-	32.5	87,558	270	49.4	**133,093**	270
TOTALS	1,593.1	**4,946,439**	309	-	-	-	910.5	**2,582,111**	275	2,503.6	**7,528,548**	297

Appendix Table C 2003 Water Demand by Irrigation System with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Irrigation System	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Drip	13.4	45,319	339	-	-	-	57.3	151,035	263	70.7	**196,354**	278
Flood	9.6	89,770	934	-	-	-	33.2	249,125	749	42.9	**338,895**	791
Golfsprinkler	21.5	172,914	805	-	-	-	8.2	67,364	826	29.6	**240,277**	810
Gun	-	-	-	-	-	-	7.9	79,329	999	7.9	**79,329**	999
Handline	379.8	2,915,872	768	-	-	-	236.7	1,825,560	771	616.5	**4,741,432**	769
Landscapesprinkler	29.3	208,863	712	-	-	-	21.8	170,622	783	51.1	**379,486**	743
Microsprinkler	1.2	22,045	1905	-	-	-	7.9	115,765	1457	9.1	**137,809**	1,514
Overtreedrip	22.5	59,469	264	-	-	-	22.8	85,947	377	45.3	**145,415**	321
Pivot	17.5	129,922	743	-	-	-	-	-	-	17.5	**129,922**	743
PivotLP	128.0	836,932	654	-	-	-	85.6	593,628	694	213.5	**1,430,560**	670
SDI	-	-	-	-	-	-	15.3	52,705	344	15.3	**52,705**	344
Sprinkler	152.9	1,141,464	746	-	-	-	171.2	1,201,480	702	324.1	**2,342,945**	723
SSGun	-	-	-	-	-	-	2.7	24,453	908	2.7	**24,453**	908
Ssovertree	4.5	24,215	539	-	-	-	5.2	29,047	563	9.7	**53,262**	552
Sssprinkler	1.2	9,697	796	-	-	-	9.3	78,782	849	10.5	**88,479**	843
Subirrig	2.6	14,043	548	-	-	-	3.4	21,941	636	6.0	**35,984**	599
Travgun	663.3	5,328,698	803	-	-	-	182.9	1,495,904	818	846.2	**6,824,602**	806
Wheelline	145.8	1,084,238	744	-	-	-	39.1	205,059	525	184.9	**1,289,297**	697
TOTALS	1,593.0	**12,083,460**	759	-	-	-	910.6	**6,447,746**	708	2,503.6	**18,531,206**	740

Appendix Table D 2003 Water Demand by Soil Texture with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Soil Texture	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Cultured Medium	1.2	22,045	1905	-	-	-	5.1	96,375	1897	6.2	**118,419**	1898
Loam	16.0	116,838	730	-	-	-	23.4	102,077	436	39.4	**218,915**	555
Loamy Sand	94.0	828,066	881	-	-	-	26.5	207,510	784	120.5	**1,035,576**	859
Organic	158.5	1,079,409	681	-	-	-	50.0	343,011	686	208.5	**1,422,421**	682
Sand	-	-	-	-	-	-	2.1	8,617	411	2.1	**8,617**	411
Sandy Loam	254.6	2,191,000	861	-	-	-	141.8	1,013,760	715	396.4	**3,204,761**	809
Sandy Loam (defaulted)	12.5	108,229	865	-	-	-	8.1	54,052	665	20.6	**162,281**	786
Silt Loam	1,042.8	7,644,672	733	-	-	-	653.3	4,620,084	707	1,696.0	**12,264,756**	723
Silty Clay Loam	13.4	93,201	694	-	-	-	0.3	2,259	698	13.7	**95,460**	695
TOTALS	1,593.0	**12,083,460**	759	-	-	-	910.6	**6,447,746**	708	2,503.6	**18,531,206**	740

Appendix Table E 2003 Water Demand by Aquifer with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Aquifer Name	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Others	109.9	888,244	808	-	-	-	29.3	141,506	483	139.2	**1,029,750**	740
Cassidy	3.8	28,044	746	-	-	-	60.5	423,748	701	64.2	**451,792**	703
Cassidy, Nanaimo Airport	-	-	-	-	-	-	1.4	10,828	774	1.4	**10,828**	774
Cedar, Yellow Point, N. O	109.2	835,863	765	-	-	-	16.8	118,227	703	126.1	**954,090**	757
Chemainus and Crofton	62.6	458,148	732	-	-	-	46.0	345,373	751	108.6	**803,521**	740
Cobble Hill	87.3	703,545	806	-	-	-	3.3	28,531	871	90.6	**732,076**	808
Cobble Hill, Duncan	-	-	-	-	-	-	0.2	882	358	0.2	**882**	358
Cobble Hill, Mill Bay	55.0	457,914	833	-	-	-	30.6	236,911	774	85.6	**694,825**	812
Cobble Hill, Shawnigan L	68.7	539,551	785	-	-	-	7.4	55,601	753	76.1	**595,151**	782
Cowichan Bay, Cobble Hill	246.1	1,953,754	794	-	-	-	358.7	2,687,659	749	604.8	**4,641,414**	767
Cowichan Station	134.5	1,058,603	787	-	-	-	19.1	161,704	846	153.6	**1,220,307**	794
Cowichan Station, Duncan	1.3	13,035	982	-	-	-	-	-	-	1.3	**13,035**	982
Deerholm, Duncan	228.2	1,690,650	741	-	-	-	71.1	324,056	456	299.3	**2,014,706**	673
Deerholm, South Duncan	63.2	383,338	607	-	-	-	33.2	236,332	711	96.4	**619,671**	643
Duncan	14.5	110,723	762	-	-	-	42.0	331,566	790	56.5	**442,290**	783
East Duncan, Maple Bay	-	-	-	-	-	-	0.2	1,205	520	0.2	**1,205**	520
Honeymoon Bay & Mesachie	-	-	-	-	-	-	7.8	52,671	673	7.8	**52,671**	673
Maple Mountain, Crofton	30.2	254,857	843	-	-	-	1.9	14,409	758	32.1	**269,266**	838
Mill Bay, Shawnigan Lake	29.9	239,060	801	-	-	-	13.5	100,596	747	43.3	**339,657**	784
Mount Sicker, Crofton - C	42.1	321,414	764	-	-	-	32.2	244,318	758	74.3	**565,731**	761
North Duncan	144.7	1,061,043	733	-	-	-	93.6	627,598	532	238.3	**1,688,642**	551
Paldi, Sahtlam	1.1	9,912	885	-	-	-	2.2	14,509	652	3.3	**24,421**	730
Panorama Ridge, Chemainus	1.2	9,177	787	-	-	-	6.4	47,523	747	7.5	**56,700**	753
Sahtlam	-	-	-	-	-	-	2.3	16,221	715	2.3	**16,221**	715
Saltair, South Ladysmith	148.9	986,351	663	-	-	-	24.1	175,946	730	173.0	**1,162,297**	672
Shawnigan Lake, Cobble Hill	2.7	26,221	954	-	-	-	0.8	6,458	819	3.5	**32,679**	924
Skutz Falls, Lake Cowicha	3.6	21,603	606	-	-	-	-	-	-	3.6	**21,603**	606
West Duncan	4.3	32,410	756	-	-	-	6.1	43,368	708	10.4	**75,777**	727
TOTALS	1,593.0	**12,083,460**	759	-	-	-	910.6	**6,447,746**	708	2,503.6	**18,531,206**	740

Appendix Table F 2003 Management Comparison on Irrigation Demand and Percolation Volumes

Water Source	Surface Water				Reclaimed Water				Groundwater				Total				
Agriculture Management	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Deep Percolation (m^3)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Deep Percolation (m^3)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Deep Percolation (m^3)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Deep Percolation (m^3)	Percolation (m^3/ha)
Poor	1,593.0	12,322,637	774	1,186,361	-	-	-	-	910.6	6,573,520	722	662,360	2,503.6	18,896,157	755	1,848,720	738
Avg	1,593.0	12,083,460	759	947,184	-	-	-	-	910.6	6,447,746	708	536,585	2,503.6	18,531,206	740	1,483,769	593
Good	1,593.0	11,844,283	744	708,007	-	-	-	-	910.6	6,321,972	694	410,811	2,503.6	18,166,255	726	1,118,818	447

Appendix Table G 2003 Percolation Volumes by Irrigation System with Average Management													
Water Source	**Surface Water**			**Reclaimed Water**			**Groundwater**			**Total**			
Agriculture Irrigation System	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Deep Percolation (m^3)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Deep Percolation (m^3)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Deep Percolation (m^3)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Deep Percolation (m^3)**	**Percolation (m^3/ha)**
Drip	13.4	45,319	3,002	-	-	-	57.3	151,035	9,855	70.7	**196,354**	**12,858**	182
Flood	9.6	89,770	15,721	-	-	-	33.2	249,125	42,470	42.9	**338,895**	**58,191**	1,356
Golfsprinkler	21.5	172,914	19,994	-	-	-	8.2	67,364	9,648	29.6	**240,277**	**29,642**	1,001
Gun	-	-	-	-	-	-	7.9	79,329	9,363	7.9	**79,329**	**9,363**	1,185
Handline	379.8	2,915,872	215,700	-	-	-	236.7	1,825,560	127,053	616.5	**4,741,432**	**342,753**	556
Landscapesprinkler	29.3	208,863	35,748				21.8	170,622	20,003	51.1	**379,486**	**55,751**	1,091
Microsprinkler	1.2	22,045	6,298				7.9	115,765	29,181	9.1	**137,809**	**35,480**	3,899
Overtreedrip	22.5	59,469	3,546				22.8	85,947	5,638	45.3	**145,415**	**9,184**	203
Pivot	17.5	129,922	5,868				-	0	0	17.5	**129,922**	**5,868**	335
PivotLP	128.0	836,932	59,842				85.6	593,628	37,970	213.5	**1,430,560**	**97,812**	458
SDI	-	-	-	-	-	-	15.3	52,705	2,874	15.3	**52,705**	**2,874**	188
Sprinkler	152.9	1,141,464	87,099	-	-	-	171.2	1,201,480	102,622	324.1	**2,342,945**	**189,721**	585
SSGun	-	-	-	-	-	-	2.7	24,453	2,980	2.7	**24,453**	**2,980**	1,104
Ssovertree	4.5	24,215	2,891	-	-	-	5.2	29,047	2,622	9.7	**53,262**	**5,512**	568
Sssprinkler	1.2	9,697	698	-	-	-	9.3	78,782	6,967	10.5	**88,479**	**7,665**	730
Subirrig	2.6	14,043	762	-	-	-	3.4	21,941	1,890	6.0	**35,984**	**2,653**	442
Travgun	663.3	5,328,698	413,232	-	-	-	182.9	1,495,904	110,832	846.2	**6,824,602**	**524,064**	619
Wheelline	145.8	1,084,238	76,782	-	-	-	39.1	205,059	14,618	184.9	**1,289,297**	**91,400**	494
TOTALS	1,593.0	**12,083,460**	947,184	-	-	-	910.6	**6,447,746**	536,585	2,503.6	**18,531,206**	**1,483,769**	593

Appendix Table H   2003 Crop Water Demand for Improved Irrigation System Efficiency and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Crop Group	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Apple	2.9	16,678	569	-	-	-	8.7	40,078	459	11.7	**56,756**	487
Berry	10.2	33,146	325	-	-	-	25.7	90,419	352	35.9	**123,565**	344
Blueberry	0.6	1,904	345	-	-	-	5.7	24,698	437	6.2	**26,602**	429
Cherry	-	-	-	-	-	-	0.1	842	595	0.1	**842**	595
Forage	1,457.0	11,024,641	757	-	-	-	686.7	5,079,015	740	2,143.7	**16,103,656**	751
Fruit	-	-	-	-	-	-	0.7	2,446	364	0.7	**2,446**	364
Golf	49.2	364,336	740	-	-	-	23.7	180,826	762	73.0	**545,162**	747
Grape	30.6	63,798	209	-	-	-	82.5	178,597	216	113.1	**242,395**	214
Nursery Floriculture	-	-	-	-	-	-	2.3	9,879	424	2.3	**9,879**	424
Nursery Shrubs/Trees	3.5	17,554	496	-	-	-	5.4	32,203	592	9.0	**49,757**	554
Pasture/Grass	8.3	56,885	686	-	-	-	13.9	99,109	713	22.2	**155,993**	703
Raspberry	1.7	6,452	390	-	-	-	2.4	8,217	349	4.0	**14,669**	366
Recreational Turf	1.6	11,983	759	-	-	-	14.3	108,200	756	15.9	**120,184**	756
Strawberry	1.8	6,002	334	-	-	-	0.6	2,028	334	2.4	**8,031**	334
Sweetcorn	5.9	23,953	408	-	-	-	0.2	1,047	447	6.1	**25,000**	409
Turf Farm	1.7	11,846	702	-	-	-	-	0	0	1.7	**11,846**	702
Vegetable	16.9	58,991	349	-	-	-	32.5	114,980	354	49.4	**173,971**	352
TOTALS	1,591.8	11,698,169	735	-	-	-	905.5	5,972,584	660	2,497.3	**17,670,753**	708

Appendix Table I   2003 Water Demand by Animal Type

Animal Type	Demand (m^3)
Beef	66,613
Dairy - dry	54,385
Dairy - milking	92,455
Goats	2,088
Horses	11,060
Poultry - broiler	7,899
Poultry - laying	4,182
Sheep	8,243
Swine	1,355
TOTALS	**248,278**

Appendix Table J Climate Change Water Demand Circa 2050 for High Demand Year with Good Management Using Current Crops and Irrigation Systems

Climate Change	rcp26			rcp45			rcp85			Average		
Year	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)
2053	2,503.6	22,689,820	906	2,503.6	13,423,260	536	2,503.6	22,796,541	911	2,503.6	**19,636,540**	784
2056	2,503.6	18,677,376	746	2,503.6	20,120,073	804	2,503.6	14,035,185	561	2,503.6	**17,610,878**	704
2059	2,503.6	11,690,410	467	2,503.6	20,858,187	833	2,503.6	22,558,709	901	2,503.6	**18,369,102**	734
Average	2,503.6	17,685,869	706	2,503.6	18,133,840	724	2,503.6	19,796,812	791	2,503.6	**18,538,840**	741

Appendix Table K Buildout Crop Water Demand for 2003 Climate Data with Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Crop Group	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)
Apple	2.9	18,304	625	-	-	-	8.7	54,314	623	11.7	**72,619**	623
Berry	10.2	94,045	921	-	-	-	25.7	216,539	843	35.9	**310,584**	865
Blueberry	0.6	1,904	345	-	-	-	5.7	27,717	490	6.2	**29,621**	477
Cherry	-	-	-	-	-	-	0.1	842	595	0.1	**842**	595
Forage	3,585.2	26,582,743	741	-	-	-	915.2	6,963,704	761	4,500.4	**33,546,447**	745
Fruit	-	-	-	-	-	-	0.7	3,456	514	0.7	**3,456**	514
Golf	49.2	364,336	740	-	-	-	23.7	180,826	762	73.0	**545,162**	747
Grape	467.7	1,120,667	240	-	-	-	135.9	347,460	256	603.6	**1,468,127**	243
Nursery Floriculture	-	-	-	-	-	-	2.3	9,879	424	2.3	**9,879**	424
Nursery Shrubs/Trees	3.5	17,554	496	-	-	-	5.4	32,203	592	9.0	**49,757**	554
Pasture/Grass	658.6	3,926,476	596	-	-	-	30.7	217,285	708	689.3	**4,143,762**	601
Raspberry	1.7	11,488	694	-	-	-	2.4	10,353	440	4.0	**21,842**	545
Recreational Turf	1.6	11,983	759	-	-	-	14.3	108,200	756	15.9	**120,184**	756
Strawberry	1.8	10,548	586	-	-	-	0.6	2,028	334	2.4	**12,577**	523
Sweetcorn	5.9	23,953	408	-	-	-	0.2	1,047	447	6.1	**25,000**	409
Turf Farm	1.7	11,846	702	-	-	-	-	0	0	1.7	**11,846**	702
Vegetable	874.9	2,911,131	333	-	-	-	83.8	371,221	443	958.7	**3,282,352**	342
TOTALS	5,665.4	**35,106,980**	620	-	-	-	1,255.5	**8,547,075**	681	6,920.9	**43,654,055**	631

Appendix Table L Buildout Crop Water Demand for Climate Change Data Circa 2050 and Good Management

Climate Change	rcp26			rcp45			rcp85			Average		
Year	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)
2053	6,927.1	53,748,201	776	6,927.1	33,787,419	488	6,927.1	56,072,627	809	6,927.1	**47,869,416**	691
2056	6,927.1	39,074,373	625	6,927.1	47,879,928	691	6,927.1	33,543,803	484	6,927.1	**40,166,035**	600
2059	6,927.1	27,146,783	392	6,927.1	49,216,742	710	6,927.1	54,669,053	789	6,927.1	**43,677,526**	630
Average	6,927.1	39,989,786	598	6,927.1	43,628,030	630	6,927.1	48,095,161	694	6,927.1	**43,904,325**	640

Appendix Table M Buildout Irrigation System Demand for 2003 Climate Data and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Irrigation System	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**	**Irrigated Area (ha)**	**Irrigation Demand (m^3)**	**Avg. Req. (mm)**
Drip	1,308.5	3,901,280	298	-	-	-	162.0	465,990	288	1,470.5	**4,367,269**	297
Flood	9.6	89,770	934	-	-	-	33.2	249,125	749	42.9	**338,895**	791
Golfsprinkler	21.5	169,424	788	-	-	-	8.2	66,441	815	29.6	**235,865**	796
Gun	-	-	-	-	-	-	7.9	76,208	960	7.9	**76,208**	960
Handline	379.8	2,856,411	752	-	-	-	236.7	1,788,261	755	616.5	**4,644,672**	753
Landscapesprinkler	29.3	206,895	706				21.8	167,028	767	51.1	**373,924**	732
Microsprinkler	1.2	22,045	1905				7.9	114,942	1447	9.1	**136,987**	1505
Overtreedrip	22.5	58,713	261				22.8	84,782	372	45.3	**143,496**	317
Pivot	17.5	129,922	743				-	0	0	17.5	**129,922**	743
PivotLP	128.0	822,022	642				85.6	583,716	682	213.5	**1,405,738**	658
SDI	-	-	-				15.3	51,786	338	15.3	**51,786**	338
Sprinkler	2,931.4	20,531,326	700	-	-	-	416.5	3,162,939	759	3,347.9	**23,694,266**	708
SSGun	-	-	-	-	-	-	2.7	23,618	877	2.7	**23,618**	877
Ssovertree	4.5	23,332	520	-	-	-	5.2	28,003	542	9.7	**51,335**	532
Sssprinkler	1.2	9,406	772	-	-	-	9.3	76,977	829	10.5	**86,384**	823
Subirrig	2.6	13,789	539	-	-	-	3.4	21,525	624	6.0	**35,314**	588
Travgun	663.3	5,230,367	789	-	-	-	182.9	1,470,980	804	846.2	**6,701,347**	792
Wheelline	145.8	1,064,323	730	-	-	-	39.1	211,128	540	184.9	**1,275,450**	690
TOTALS	5,666.5	**35,129,025**	620	-	**-**	-	1,260.6	**8,643,450**	686	6,927.1	**43,772,475**	632

Appendix Table N Buildout Demand by Aquifer for 2003 Climate Data and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Aquifer	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)
Others	1,598.5	9,812,060	614	-	-	-	61.8	307,424	498	1,660.3	**10,119,484**	609
Cassidy	47.2	284,864	604	-	-	-	194.2	1,332,161	686	241.3	**1,617,025**	670
Cassidy – Nanaimo Airport	7.8	62,101	797	-	-	-	23.3	176,095	755	31.1	**238,196**	766
Cedar, Yellow Point, N. O	320.1	1,915,335	598	-	-	-	23.3	142,265	611	343.3	**2,057,600**	599
Chemainus and Crofton	134.7	903,253	671	-	-	-	77.5	508,680	657	212.2	**1,411,933**	665
Cobble Hill	111.4	759,660	682	-	-	-	3.3	27,952	853	114.7	**787,612**	687
Cobble Hill, Duncan	30.3	174,563	577	-	-	-	0.2	882	358	30.5	**175,444**	575
Cobble Hill, Mill Bay	200.6	1,305,142	651	-	-	-	30.6	231,946	758	231.2	**1,537,088**	665
Cobble Hill, Shawnigan L	104.8	749,094	715	-	-	-	7.4	54,591	739	112.2	**803,685**	716
Cowichan Bay, Cobble Hill	430.8	2,995,926	695	-	-	-	387.0	2,808,967	726	817.8	**5,804,893**	710
Cowichan Station	134.5	1,037,654	771	-	-	-	19.7	161,849	821	154.2	**1,199,504**	778
Cowichan Station, Duncan	1.3	12,764	961	-	-	-	-	-	-	1.3	**12,764**	961
Deerholm, Duncan	841.8	4,806,216	571	-	-	-	80.4	391,509	487	922.1	**5,197,725**	564
Deerholm, South Duncan	128.6	769,809	599	-	-	-	33.2	231,143	695	161.8	**1,000,952**	618
Duncan	87.6	527,684	602	-	-	-	66.3	445,368	672	153.9	**973,052**	632
East Duncan, Maple Bay	60.3	321,102	532	-	-	-	0.2	1,182	510	60.5	**322,284**	532
East shore of Mesachie La	2.5	13,440	534	-	-	-	-	-	-	2.5	**13,440**	534
Honeymoon Bay & Mesachie	175.0	823,727	471	-	-	-	7.8	51,594	659	182.8	**875,321**	479
Ladysmith, BC	-	-	-	-	-	-	0.1	479	949	0.1	**479**	949
Maple Mountain, Crofton	68.5	409,089	597	-	-	-	10.8	76,833	708	79.4	**485,922**	612
Mill Bay, Shawnigan Lake	145.8	926,629	636	-	-	-	13.5	98,109	728	159.3	**1,024,738**	643
Mount Sicker, Crofton - C	150.3	1,011,377	673	-	-	-	80.7	656,650	814	231.0	**1,668,027**	722
North Duncan	389.6	2,393,733	614	-	-	-	97.6	639,519	560	487.1	**3,033,252**	541
Paldi, Sahtlam	47.4	261,016	551	-	-	-	2.2	14,366	645	49.6	**275,382**	555

Appendix Table N Buildout Demand by Aquifer for 2003 Climate Data and Good Management - continued

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Aquifer	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m^3)	Avg. Req. (mm)
Panorama Ridge, Chemainus	4.5	31,808	714	-	-	-	6.4	46,468	730	10.8	**78,276**	724
Sahtlam	82.0	690,776	842	-	-	-	2.3	15,937	702	84.3	**706,713**	839
Saltair, South Ladysmith	187.5	1,168,363	623	-	-	-	24.1	172,333	715	211.6	**1,340,696**	634
Shawnigan Lake, Cobble Hill	69.7	456,044	655	-	-	-	0.8	6,458	819	70.5	**462,501**	656
Skutz Falls, Lake Cowicha	3.6	20,862	586	-	-	-	-	-	-	3.6	**20,862**	586
South Thetis Island	50.2	243,695	485	-	-	-	-	-	-	50.2	**243,695**	485
West Duncan	49.7	241,239	485	-	-	-	6.1	42,691	698	55.8	**283,930**	599
TOTALS	5,666.5	**35,129,025**	620	-	-	-	1,260.6	**8,643,450**	686	6,927.1	**43,772,475**	632