Irrigation Water Demand Model

Technical Description

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by:

Ron Fretwell
RHF Systems Ltd.
Kelowna, BC

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Purpose

This document provides technical descriptions of the structure, tables, and methodology used to calculate a theoretical water demand within the Irrigation Water Demand Model application. This description doesn't cover the use of the MS Access forms-based user interface; that's described in a separate User's Guide document. Instead, this discussion focuses on the rules and formulae used to calculate the water demand, and on the tables of factors that can be modified to adjust the calculations for different conditions.

The original specifications for the modeling methodology were laid out in the Request for Proposal for the application's development and that document has been included as an appendix since it provides additional information and rationale for the calculations. There have been several changes and additions to the processes outlined in the RFP, however, and those changes are highlighted in the body of this document.

Organization and New Terms

The organization of this description follows the general steps outlined in the RFP; it develops the overall equation used to calculate the water demand and points to later sections and appendices for further details on the individual terms of the equation. The names and abbreviations used in the RFP have generally been retained, but there have been new terms added to accommodate the changing requirements:

earlyEvaporationFactor

- a factor used during the pre-growing season stage to create a modified Effective Precipitation from the actual daily precipitation measurement
- used as part of the annual Soil Moisture Deficit calculation

maxStoredMoisture

- a soil-dependent factor representing the maximum amount of water that a soil type can hold

storedMoisture

- an amount of water retained in the soil "reservoir" and available to the crops to offset the daily evapotranspiration
- depends on the soil type and is increased by excess precipitation and decreased by each day's moisture requirements
- used for both the annual Soil Moisture Deficit calculation and for the daily Irrigation Requirements during the growing season

maximumEvaporation

- a soil-dependent maximum depth of water that can be drawn from the soil through evaporation in the pre-growing season stage
- used as part of the annual Soil Moisture Deficit calculation

swFactor

- a soil water factor reflecting the amount of water that crops can extract from the different soil types
- dependent on the soil's maximum soil water deficit, which in turn depends on the characteristics of the soil, and the crop's rooting depth and availability coefficient

stressFactor

- used primarily for grass crops, a multiplier that reflects the fact that some crops don't get watered to their optimum amount; grass used for dust control, for example, can be allowed to dry out to some degree without affecting its purpose

CWR

- Crop Water Requirement; the amount of water required for a crop after taking the climate moisture deficit, soil water factor and any stress factor into account, but before any irrigation efficiencies have been introduced

greenhouseLeachingFactor

- multiplier used for greenhouses to reflect the purposeful over-watering for leaching purposes

soilPercFactor
- factor used to reflect the amount of water lost to deep percolation
- for greenhouses, the greenhouseLeachingFactor is used as the soilPercFactor

IWDperc
- the part of the irrigation water demand considered lost to deep percolation
- depends on a soilPercFactor which is controlled by the Irrigation Management Practices setting (good management means less percolation loss)

Irrigation Water Demand Equation

The Irrigation Water Demand equation is developed as a series of steps to mimic the layout in the RFP specifications. It's outlined here first since it is most likely to be referenced when working to adjust the various factors for calibration. The derivations of the individual terms used in the equation are described after the overall equation.

<u>1. Annual Soil Moisture Deficit (SMD)</u>

The annual Soil Moisture Deficit represents the amount of water that has to be added to the soil at the beginning of the growing season in order to start off with a full soil reservoir. Although the same term is used, the calculation methodology for the SMD has changed radically from the description in the original RFP:

1. For each crop type, determine the start of the growing season (see *Growing Season Boundaries*)
2. Start the initial storedMoisture depth on January 1 at the soil's maximum evaporation depth
3. 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 evapotranspiration (ET0)
    b. the effective precipitation:
       EP = actual precipitation * earlyEvaporationFactor
    c. daily Climate Moisture Deficit (CMD) = ET0 – EP
    d. storedMoisture = previous day's storedMoisture – CMD

A negative daily CMD (precipitation in excess of the day's evapotranspiration) adds to the stored moisture level while a positive climate moisture deficit reduces the amount in the stored moisture reservoir. The stored moisture balance is capped at 0 on the low end and the maximum evaporation depth (maxEvaporation) at the other end on a daily basis; if there is enough precipitation to fill the reservoir beyond the maximum evaporation level, that extra moisture is ignored.

On the day before the start of each crop's growing season, the annual SMD value is finalized as the difference between the stored moisture at that time and the maximum evaporation:

SMD = maxEvaporation – storedMoisture

<u>2. Crop Evapotranspiration (ETc)</u>

The evapotranspiration for each crop is calculated as the general ET0 multiplied by the crop coefficient Kc:

ETc = ET0 * Kc

The crop coefficients are based on crop-specific polynomial equations accounting for the plant growth and ground coverage stages. For alfalfa crops, there is a set of equations corresponding to different cuttings throughout the growing season. For greenhouses, the crop coefficient is a fixed factor based on the month of the year.

3. Climate Moisture Deficit (CMD)

During the growing season, the daily Climate Moisture Deficit is calculated as the crop evapotranspiration (ETc) less the Effective Precipitation (EP); the effective precipitation is 75% of 5mm less than the actual precipitation (anything less than 5mm of rainfall is considered to evaporate without providing any irrigation benefit):

EP = (precip – 5) * 0.75
CMD = ETc – EP

If the precipitation is 5mm or less, then the effective precip is 0. Greenhouses automatically have an EP value of 0.

During each crop's growing season, a stored moisture reservoir methodology is used that's similar to the calculation of the annual Soil Moisture Deficit. At the beginning of the growing season, the starting point for the stored moisture is the maximum stored moisture depth under the assumption that any soil moisture deficit has been satisfied. Then, on a daily basis, the stored moisture level is used towards satisfying the climate moisture deficit to produce an *adjusted Climate Moisture Deficit* (CMDa):

CMDa = CMD – storedMoisture

If the storedMoisture level exceeds the day's CMD, then the CMDa = 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 stored moisture setting (maxStoredMoisture).

4. Crop Water Requirement (CWR)

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

CWR = CMDa * swFactor * stressFactor

5. Irrigation Requirement (IR)

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

IR = CWR * Df / Ie

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

6. Irrigation Water Demand (IWDperc and IWD)

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

IWDperc = IR * soilPercFactor

The final Irrigation Water Demand is then the Irrigation Requirement plus the loss to percolation:

IWD = IR + IWDperc

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 derivations, generally using TSUM or Growing Degree Day accumulations
- the growing seasons overrides table
- irrigation overrides

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 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 Irrigation start day on the User Interface form would override both of the other dates, resulting in a final season start of day 105.

The use of the growing season overrides table and the Irrigation overrides are outlined in the IWDM User's Guide. This section describes the rules used to establish growing season boundaries based on the internal calculations of the model. These rules have changed significantly over those listed in the RFP, many moving to a TSUM (summed temperature) accumulation methodology. 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 Growing Degree 5 end date or the first frost.

Corn (silage corn)

- uses the corn_start and silage_corn_end dates for the season boundaries

Sweetcorn, Potato, Tomato, Pepper, Strawberry, Vegetable

- corn_start date for the season start
- corn start plus 110 days for the season end

Cereal

- GDD5 start for the season start and the GDD5 start plus 130 days for the season end

AppleHD, AppleMD, AppleLD, Asparagus, Berry, Blueberry, Ginseng, Nuts, Raspberry, Sourcherry, Nursery

- season start: (0.8447 * tsum600_day) + 18.877
- standard end of season

Pumpkin

- corn_start date, standard end of season

Apricot

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

CherryHD, CherryMD, CherryLD

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

Grape

- season start: (0.8447 * tsum600_day) + 18.877
- standard end of season

Peach, Nectarine
- season start: (0.8438 * tsum450_day) + 19.68
- standard end of season

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

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

Grass, Forage, Alfalfa, Golf, TurfFarm
- season start: later of the GDD5 start and the tsum300_day
- standard end of season

Domestic, Yard, TurfPark
- season start: later of the GDD5 start and the tsum400_day
- standard end of season

Greenhouse
- fixed season of February 1 – October 31

Evapotranspiration (ET0)

The ET0 calculation is outlined in detail in the RFP, and the steps described there are followed exactly, with the exception of the following corrections to the listed equations:

Step 6 – Inverse Relative Distance Earth-Sun

Instead of a fixed 365 days as a divisor, the actual number of days for each year (365 or 366) is used.

Step 13 – Net Longwave Radiation

The additions to the Tmax and Tmin values to convert from Celsius to Kelvin area listed as 237.15 and 237.16 respectively in the RFP; these should both be 273.16.

Step 19 – Evapotranspiration

For consistency, a temperature conversion factor of 273.16 was used instead of the rounded 273 listed.

Availability Coefficient (AC)

The availability coefficient is taken directly from the crop factors table (*crop_factors*) based on the cropId value.

Rooting Depth (RD)

Read directly from the crop factors table.

Stress Factor (stressFactor)

Read directly from the crop factors table.

Available Water Storage Capacity (AWSC)

The available water storage capacity 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 * AWSC * AC

Deep Percolation Factor (soilPercFactor)

For the greenhouse "crop", the greenhouse leaching factor from the main application configuration table (*iwdm_configuration*) is used as the soil percolation factor. For other crops, the factor depends on the soil texture, the maximum soil water deficit, 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 maximum soil water deficit value that matches or exceeds the value calculated for the current landuse 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, a soil type of SL and an irrigation system of Ssovertree would retrieve the percolation factor associated with the MSWD index value of 75 in the current table (presently, there are rows for MSWD 50 and 75 for SL and Ssovertree).

Maximum Evaporation Factor (maxEvaporation)

Read directly from the soil factors table.

Irrigation Efficiency (Ie)

Read directly from the irrigation factors table (*irrigation_factors*).

Maximum Stored Moisture Depth (maxStoredMoisture)

The maximum stored moisture value is set as one half of the maximum soil water deficit (MSWD).

Soil Water Factor (swFactor)

For the greenhouse "crop", the soil water factor is set to 1. For other crops, it's interpolated from a table (*soil_water_factors*) based on the maximum soil water deficit (MSWD). For Nurseries, the highest soil water factor (lowest MSWD index) in the table is used; otherwise, the two rows whose maximumSoilWaterDeficit 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 and 100 mm respectively, a calculated MSWD value of 82.5 would return a soil water factor of

0.95 + ((82.5 – 75) / (100 – 75) * (0.9 – 0.95)) = 0.935

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)

Taken from the main application configuration table (*iwdm_configuration*).

Crop Coefficient (Kc)

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 equaling 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:

Kc = (0.0000000031 * 35^4) + (-0.0000013775 * 35^3) + (0.0001634536 * 35^2) + (-0.0011179845 * 35) + 0.2399004137
= 0.346593241

Many of the coefficients have been modified from the values listed in the RFP. See the crop factors table for the current values.

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.

Growing Degree Days

The Growing Degree Day calculations are much the same as those outlined in the RFP, but there have been changes to the tests that reset the searches for the start and end of the GDD accumulations.

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 mean temperatures matching or exceeding the base temperature. This is a slightly different test than outlined in the RFP where the mean temperature has to strictly exceed the base temperature for 5 days. The search for the start day gets reset if a killing frost (< -2 degrees C) occurs, even after the accumulation has started. The search also restarts if there are 2 or more consecutive days of minimum temperatures <= 0 C. The GDD start is limited to julian days 1 – 210; if the accumulation hasn't started by that point, then it's unlikely to produce a reasonable starting point for any crop.

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 the mean temperature fails to reach the base temperature (strict *less than* test) or the first killing frost (-2 C).

During the GDD accumulation period, the daily contribution is the difference between the day's mean temperature and the base temperature, as long as the mean temperature isn't less than the base temperature:

GDD = Tmean – BaseT; 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 minimum temperature of 0 degrees or less
- the first fall frost is the first day between days 240 and the and of the year where the minimum temperature drops to 0 degrees or less
- the killing frost is the first day on or after the first fall frost where the temperature drops to or below –2 C.

Corn Heat Units

The Corn Heat units calculation is slightly different than the RFP description in that each of the 2 terms (Tmax and Tmin) in the numerator of the equation gets set to 0 individually if the term is negative, which can be different than evaluating the whole equation and then setting it to 0 if negative:

term1 = (3.33 * (tmax - 10)) - (0.084 * (tmax - 10) * (tmax - 10)); 0 if negative
term2 = 1.8 * (tmin - 4.44); 0 if negative
CHU = (term1 + term2) / 2

Corn Season Start and End

The corn season boundary derivations are similar to the Growing Degree Day determinations. The start day is established by 3 consecutive days where the mean temperature is 11.2 degrees or warmer. As in the case of the GDD calculations, the search for the corn season start day gets reset if the minimum temperature drops to –2 or less or if there are 2 or more consecutive days of minimum temperatures between –2 and 0 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 mean daily temperatures reaches that number. For example, the TSUM400 day is the day where the sum of the positive mean temperatures starting at January 1 sum to 400 units or greater.

Days where the mean temperature falls below 0 are simply not counted – they don't restart the accumulation sequence.

Residential, Industrial, Commercial and Institutional Water Use

The initial scope of the Irrigation Water Demand Model was limited to agricultural crops plus a few larger non-agricultural areas such as golf courses and parks that use a significant amount of water. This scope was later expanded first to include water used for domestic outdoor irrigation, and then to indoor uses under several different categories.

Domestic Outdoor Irrigation

An image analysis process was used to identify the irrigated portion of each residential property and to produce a table of property identifiers and irrigated areas. These areas were then applied to the database used for the Irrigation Water Demand modeling by calculating the percentage of each residential property under irrigation and storing that proportion in the *iwdMult* column. The Irrigation Water Demand Model calculates the theoretical demand as a depth in millimeters for each combination of climate cell, crop type, irrigation system, and soil texture; the demands are then converted to volumes as the data is summarized by multiplying the calculated depth by each polygon's area. The *iwdMult* value is included as a multiplier at that point so that it can be used to, in effect, reduce the apparent area of a polygon. For cropped areas that have been designated through surveys and mapping, the multiplier is fixed at 1.0; for areas derived statistically such as for residential properties, the multiplier reflects the irrigated proportion of the lot.

This statistical irrigation area process was applied only to parcels that did not have any kind of identified crop. The assumption was that any parcels that had an associated crop had been described completely under the agricultural inventory survey including, where appropriate, explicit identification of yard areas. Excluding surveyed parcels from the statistical irrigated landscape process prevented a potential double-counting of landscaped areas.

The domestic irrigation areas identified through the image analysis process have been limited to properties zoned R (Urban Residential) and RU (Rural Residential) through the zoneCat code.

Indoor Water Use

The BC Assessment Authority *Actual Use* codes were obtained for all properties in the Okanagan and assigned daily per-parcel water uses based on metered results from key municipalities. For example, a single family residential dwelling (actual use code 000) was assigned a use of 0.45716 cubic metres per day. These daily use values were stored in the Water Demand Model source databases in an *iwdAddDaily* column, which gets multiplied by the number of days in a selected reporting period and added to the other water use calculations.

The actual use codes were further classified into 4 categories for reporting purposes:

Actual Use Code Range	Reporting Class
000 – 099	Residential
200 – 300	Commercial
400 – 499	Industrial
500 – 599	Commercial
600 – 699	Institutional

Actual use codes other than those described above don't occur on the current Okanagan source database.

Application Structure and Setup

Application Files

The Irrigation Water Demand application is an MS Access application consisting of several Access database files, a large set of climate data files in an ascii text file (ESRI ascii grid) format, various supporting files such as image icons and help files, and a spatial map in ESRI shape file format that can be used to display the modeling results thematically or, for users experienced with GIS and database processes, to select the modeling areas geographically.

There is no explicit installation process; implementation consists of unpacking the application files onto a computer and, if the default structure isn't used, modifying the internal file and folder pointers to let the application know where to find its components. Directory locations are not hardcoded; the different parts of the application could be placed anywhere including splitting things across logical or physical disk drives. There is a default structure, however, and it's expected that this default will be suitable for most installations.

By default, the main application structure starts from an *\iwd_model* top-level folder. This is the folder referred to below as the *application installation location*; it's the subdirectory that contains the main application database file *iwdm.mdb*. It's opening this file that starts the application, either through an explicit selection from MS Access or by referencing it through a desktop shortcut.

There are configuration tables, one in the main application database and one in each of the modeling area configuration databases, that contain references to the folders storing the other components of the application. In most cases, a symbolic token *appinstall* can be used as part of the references to refer to the application installation directory as the starting point; a specification of *appinstall\okanagan\climate_databases* would refer to the \climate_databases subfolder in the okanagan branch underneath the installation directory (e.g. *\iwd_model\okanagan\climate_databases*). Refer to the Application Configuration Table discussion (Appendix A) for a description of the folder references.

The main application structure includes the following folders, by default located directly underneath the application installation directory:

\help_files

- a set of image files in portable network graphics format used to display brief descriptions of the User Interface forms when the Help buttons are pressed

\icons

- image and icon files used in the application's User Interface and on the summary reports
- the .ico files are suitable for use in a desktop link (particularly the mal4.ico file representing the BC sunrise logo)

\areaname (e.g. okanagan)

- branch containing the area-specific files and subfolders

Each of the area branches contains:

\case_studies

- used to output all modeling results into databases with the names given to each Case Study
- the files in this location are the only components of the IWDM application that might be candidates for regular backups (although the case studies are relatively fast and easy to reproduce); none of the other parts of the system change during modeling

\climate_databases

- contains a single *iwdm_climate_sources* database plus a database for each of the climate models (e.g. *actuals* or *hadcm3.b2*)

- the *iwdm_climate_sources* database contains pointers to the raw ascii climate files and a set of factors associated with each cell in the climate grid (elevation, latitude, etc.)
- each of the the model databases contain tables for each year carrying derived indices such as the first and last frosts, and TSUM accumulation days

Climate Data Files

The raw climate data files are large, currently requiring about ½ Gb per year per climate model. The dozen or so models available at the time of development take up approximately 720 Gb of disk space. It's expected that these files will reside in a separate location, and likely on a separate hard drive, than the application files. The default directory structure for the climate files is a high level folder called \iwdm_climate_sources with a subfolder for each modeling area (e.g. okanagan), a subfolder for each model (e.g. hadcm3.b2) and a subfolder under that for each year (e.g. 1961). Assuming all are stored on the D: drive, the default structure would be:

```
\iwdm_climate_sources
    \okanagan
        \actuals
            \1960
            \1961
            …
        \hadcm3.b2
            \1961
            \1962
            …
    \nicola
        \actuals
            \1960
            \1961
            …
        \cgcm3.a2
            \2003
            \2004
            …
```

Each climate data file (minimum and maximum daily temperature, daily precipitation) is separately referenced in the *climate_sources* table in the watershed's *iwdm_climate_sources* database, so it's possible to create any structure and to spread the file locations out over any number of disk drives. However, the configuration tool that automatically runs when the application is first opened after installation expects that the default structure is being used. It requests a single drive letter for the climate files for each modeling area and it sets the drive reference for all of the climate files to that letter, leaving the rest of the paths and file names intact. If you want to use a different structure than the default, or split the climate files across disk drives, then you must manually alter the file name references in the *climate_sources* tables. The structure of those table is simple and obvious; for each climate model, year and julian day, the full path and file name of each of the three data files is listed using the columns *tmin_source*, *tmax_source* and *precip_source*.

Other Files

As the modeling process runs, it records the times of different stages as well as any error or warning conditions to a text file in the application installation location called *iwdm_log.txt*. This file can be opened with any text editor or word processor, including the *Notepad* and *Wordpad* utilities. It can be interesting in terms of monitoring the time taken for various processing steps, and it can also help to identify cases where the source data might contain unexpected values (empty or missing irrigation types, for example). The file is recreated for each new modeling session, so it doesn't need to be cleared or managed for space considerations.

Each of the modeling areas (watersheds) has its own configuration database *iwdm_configuration.mdb* located in the high level of the area's branch. For example, the Okanagan's configuration table is located by default in:

\iwd_model\okanagan\iwdm_configuration.mdb

These databases contain settings that are specific to the modeling area, such as pointers to additional components of the model located in the area's branch, and factors tables that can be adjusted for each area separately (e.g. the growing season overrides table).

The IDW model uses all or a subset of the rows in a *Polygons* table in the database specified on the User Interface form as the *Polygons Source,* copying that subset into a new *Polygons* table in the Case Study database. That means that the source of each modeling run can be the resulting extract from a previous case study. In most cases, however, each modeling run will be started from the original source table holding the records for the entire modeling area. That database, by default, is the *IWDM Original Source.mdb* file located at the top of each modeling area's branch. Once again, the database name and location are configurable using the area-specific configuration tables.

Some of the results of the modeling process are suitable for displaying as a thematic map. For example, each crop field's total annual irrigation water demand, expressed as a depth in millimeters, can give a good visual depiction of where water use is highest in a particular area. The *Create Thematic Maps of Results* selection on the main application menu offers a few pre-determined choices for thematic displays; it builds a table called *map_themes* in the Case Study database with the selected statistic and then copies those results into the *mapTheme* field in an ESRI Shape file referenced in the application configuration table as the *thematic_map_reference*. By default, this reference is to an *IWDM_ovl* shape file set at the top of the modeling area's branch.

Application Password

The application database is protected through a simple password mechanism to avoid inadvertent modifications to the code or tables of factors. To change the password, the database has to be opened in exclusive mode:

1. Start MS Access explicitly (not by using the IWDM shortcut or double clicking on the database file).
2. Use the File and Open selections from the top menu bar (not the recently opened databases listed on the right side of the display)
3. Browse to the *iwdm.mdb* file and highlight it, but don't double-click it
4. Use the Open dropdown list on the lower right of the Open dialog to select *Open Exclusive*
5. Type the current application password and hold down the SHIFT key as you press Enter or click OK
6. From the Access menu bar at the top of the display, choose Tools/Security/Unset Database Password
7. Type in the current password
8. Select Tools/Security/Set Database Password and enter the new password
9. Close the application

Appendix A - Configuration Tables

There are two configuration tables carrying parameters and switches that control different parts of the Irrigation Water Demand Model:

- an application level table in the *iwdm.mdb* database in the installation folder
- an area-specific table in the *iwdm_configuration.mdb* database at the top of each modeling area's branch

In both cases, the table is named *iwdm_configuration*.

Some of the values describe locations on the computer, and most of those allow for either a fixed location (e.g. *d:\iwdm_model*) or a location relative to the folder containing the application database (*iwdm.mdb*). In the latter case, the token *appinstall* translates into the application installation directory so that *appinstall\help_files* means the *help_files* subdirectory underneath the location where the *iwdm.mdb* application database lives.

The only values that are likely candidates for modification for the water demand calculations are the greenhouse leaching factor and the early season evaporation factor; the rest are either changeable from the interface forms, set by the initial configuration routine, or unlikely to require adjustment.

To reach the main application configuration table for modification, open the MS Access application database (*iwdm.mdb*) in the mode that bypasses the initial startup form: hold down the SHIFT key as you press the Enter key or click on the OK button after typing in the application password. Choose the Tables object and double-click on the *iwdm_configuration* table to open it for modification. For the area-specific configuration tables, you don't have to enter a password or hold down the SHIFT key; just open the iwdm_configuration database at the top of the area's branch.

The application configuration table contains the following parameters:

system_configured
- used by the application start up routines to control whether or not to raise the configuration form when the application is opened
- set to **Y** by the application after the configuration routines have been completed

helpfiles_location
- directory containing the help files (portable network graphics images) used to provide brief descriptions of the application's User Interface forms

icons_location
- directory containing the icons and symbols used in the User Interface and on the output reports

week_type
- a code that indicates what type of week definition to use when rolling up the daily calculations to a weekly period
- currently the code **obwb** is the only option that has been completely developed and tested; the obwb (Okanagan Basin Water Board) definition of each year's weeks is that the last week in December always has 8 days and the last week of February has 8 days in leap years

gdd_bases_string
- determines which growing degree day sets (base temperatures) are calculated and stored by the climate data pre-process routines
- although the setting is currently **5,10**, the model always calculates GDD5 and GDD10 stats, even if not specified in the string, since these are used as the basis of some of the growing season boundaries

irrigation_management_practice
- default setting for the Irrigation Management Practices code on the User Interface forms

bytes_per_polygon_dailies_row

- an estimate of the number of bytes output to the Case Study database for each daily calculation so that the User Interface can alert the user to cases that may fail due to MS Access's 2Gb database file size constraint
- this is currently set at 13000, but it can only be an approximate value since the actual space required depends on things like the climate-influenced growing season length

use_season_overrides_table

- default setting for the User Interface choice as to whether or not the growing season overrides table should be used

modeling_area

- the name of the selected modeling area (e.g. okanagan)

Each of the area-specific configuration tables contains:

original_source_database

- path and file name of the MS Access database carrying the application's primary *Polygons* source table
- this is the table that shows in the interface as the *Original Landuse Data Source*

results_location

- directory into which the modeling results for each case study are written

climate_databases_location

- directory containing the climate databases
- these are not the raw climate files, but instead tables of pointers to those climate files and metadata about them such as each climate cell's first and last frost days for each year

greenhouse_leaching_factor

- multiplier used as the soil percolation factor for greenhouses

early_season_evaporation_factor

- used as a multiplier for the daily precipitation when calculating the pre-growing season soil moisture content

thematic_map_reference

- the path and name of an ESRI Shape file used to display the results of the IWD calculations thematically
- the *Create Thematic Maps of Results* selection from the main menu updates a *mapTheme* column in the shape set referenced by the value

Appendix B - Factors Table Structures

There are quite a few sets of factors used in the Irrigation Water Demand model. The casual user of the application isn't expected to deal with these factors since they require fairly detailed knowledge of how the different parts of the water demand equations function. In most cases, once established, these tables won't require modification. However, in the initial calibration stages, and as new modeling areas and crops are added, some adjustment may be necessary.

To reach the factors tables for modification, open the MS Access application database (*iwdm.mdb*) in the mode that bypasses the initial startup form: hold down the SHIFT key as you press the Enter key or click on the OK button after typing in the application password. Choose the Tables object and double-click on the table to open it for modification.

In most cases, rows can be added to the tables to accommodate new source information (e.g. new irrigation systems), new Irrigation Management Practices codes, etc. and the modeling routines will recognize and handle them. Some of the summary reports reference the distinct set of values explicitly, however, so modifications to the report templates could be required for that type of change.

Most of the examples of the factors tables in the following discussions are just that: examples showing a few of the rows for the purposes of describing the structures. The complete listings of the tables can be found in a later appendix.

Alfalfa Cuttings table (alfalfa_cuttings)

Most crops use a single equation to calculate their crop coverage coefficient; the equation takes into account the number of days into the season. Alfalfa, however, can have several cuttings over the course of the growing season, and different equations are used depending on which cutting is being considered (first, intermediate or last). The alfalfa cuttings table defines the number of days in each growing period based on the total length of the growing season.

growing_season_length

- length of the alfalfa growing season (days)

first_cut_days

- number of days in the first cutting period

second_cut_days

- number of days in the second cutting period

third_cut_days

- number of days in the third cutting period (may be 0 if the growing season isn't long enough to achieve 3 cuttings)

fourth_cut_days

- number of days in the fourth cutting period (may be 0)

rationale

- a comment as to the reason for the number of days settings

alfalfa_cuttings

growing_season_length	first_cut_days	second_cut_days	third_cut_days	fourth_cut_days	rationale
120	55	55	0	0	can't get 3rd cut without 35 days for each after first; stay with 55 days for 2nd cut
121	55	55	0	0	
122	55	55	0	0	
123	55	55	0	0	

Crop Factors and Coefficients table (crop_factors)

The crop factors table contains, for each cropId listed in the source data, factors such as the rooting depth and stress factor, and the terms of the crop coefficients equations.

cropId
- crop identifier as per Landuse source

cropGroup
- grouping code for combing individual crops for some summary reports (e.g. Apple to include AppleHD, AppleMD, AppleLD)

rootingDepth
- the crop's rooting depth in metres

availabilityCoefficient
- factor reflecting the crop's ability to extract water from the soil

dripFactor
- water use reduction factor for drip irrigation systems

stressFactor
- water use reduction factor primarily for grass crops used for purposes such as dust control rather than for production purposes

comments
- general comments field to track rationale and notes about changes

coefficient_4
- the highest (4^{th} power) term in the crop coefficients equation

coefficient_3
- 3^{rd} power term

coefficient_2
- 2^{nd} power term

coefficient_1
- single power term

coefficient_0
- constant term

crop_factors

cropid	crop Group	rooting Depth	availability Coefficient	drip Factor	stress Factor	comments	coefficient_4	coefficient_3	coefficient_2	coefficient_1	coefficient_0
Potato	Vegetable	0.6	0.35	0.75	1		0	-0.0000013745	0.0002449713	-0.0028533427	0.3968596247
Pumpkin	Vegetable	0.5	0.35	0.75	1		0.0000000246	-0.0000071579	0.0005705239	-0.0045023884	0.3996233199
Raspberry	Berry	1.2	0.5	0.7	1		0.0000000053	-0.0000024204	0.0002930277	-0.0025162017	0.2434784686
Sourcherry	Cherry	0.9	0.4	0.8	1		0.0000000011	-0.0000006128	0.0000789103	0.0034721982	0.4338842227
Strawberry	Berry	0.6	0.5	0.75	1		0.000000011	-0.000004549	0.0004722314	-0.0039611341	0.203054929
Sweetcorn	Vegetable	0.9	0.55	1	1		-0.0000000153	-0.0000005932	0.0002543513	-0.0015212354	0.4024757053

Greenhouse Factors table (greenhouse_factors)

The greenhouse factors tables hold the water use factors for greenhouses by month number. The water use factor is applied as the crop coefficient for greenhouse “crops”.

monthNumber

- month number (integer 1 – 12)

greenhouseFactor

- water use factor

greenhouse_factors	
monthNumber	**greenhouseFactor**
1	0
2	2.7473
3	1.7604
4	1.5845
5	1.9698
6	1.9522
7	1.3481
8	1.3687
9	1.5298
10	1.5507
11	0
12	0

Irrigation Efficiencies table (irrigation_factors)

The table holds the efficiency factors for each irrigation type.

irrigId

- irrigation identifier as it appears on the Landuse source

irrigationEfficiency

- irrigation efficiency factor
- used as a divisor in the Irrigation Requirements calculation

comments

- general comments field to track rationale and notes about changes

irrigation_factors		
irrigid	**irrigationEfficiency**	**comments**
Blank	0.72	Unknown system - use Sprinkler parameters
Drip	0.92	
Flood	0.4	
Golfsprinkler	0.72	
Gun	0.55	
Handline	0.7	

Soil Factors table (soil_factors)

Stores the water storage capacity and maximum evaporation depths for each soil texture.

soilId
- soil identifier as per the Landuse source

soilClass
- textual description of the soil texture

availableWaterStorageCapacity_mm
- soil's water storage capacity in millimetres

maximumEvaporation
- maximum evaporation depth in millimeters

soil_factors			
soilid	**soilClass**	**availableWaterStorageCapacity_mm**	**maximumEvaporation**
C	Clay	200	29
default	Sandy Loam (defaulted)	125	20
FSL	Fine Sandy Loam	142	21
HC	Heavy Clay	208	30
L	Loam	167	22
LS	Loamy Sand	100	14
O	Organic	250	36
S	Sand	83	12
SCL	Sandy Clay Loam	167	23
SI	Silt	167	23
SIC	Silty Clay	208	28
SICL	Silty Clay Loam	200	27
SIL	Silt Loam	192	25
SL	Sandy Loam	125	20
VCSL	Very Coarse Sandy Loam	83	12
VFSL	Very Fine Sandy Loam	167	23

Soil Percolation factors table (soil_percolation_factors)

Holds the factors used to calculate the water losses due to deep percolation for each combination of soil type, maximum soil water deficit and irrigation type for different management practice assessments (good, average, poor). This table has a very un-relational structure to it (duplicate and missing values, repeating groups) because it's sourced from, and managed in, an external Excel spreadsheet.

SoilId
- soil identifier as per the Landuse source

Soil Class (not used by the IWDM calculations)
- description of the soil texture

MSWD
- maximum soil water deficit, categorized into discrete steps

Infiltration Rate (not used by the IWDM calculations)
- rate of infiltration in millimetres

For each irrigation system type and management practice, a percolation factor using a column name produced from the concatenation of the irrigation identifier (irrigId), a blank space, a hyphen, a blank space, and the management practice code:

Gun – poor
- percolation factor for Gun irrigation under poor irrigation management

Gun – good
- percolation factor for Gun irrigation under good irrigation management

etc.

See the complete table listing in Appendix G for the structure of the table.

Soil Water Factors table (soil_water_factors)

Stores a set of multipliers for calculating the Crop Water Requirement from the Climate Moisture Deficit.

maximumSoilWaterDeficit
- maximum soil water deficit, categorized into discrete steps

soilWaterFactor
- soil water factor used in the CWR calculation

soil_water_factors

maximumSoilWaterDeficit	soilWaterFactor
25	1.05
50	1
75	0.95
100	0.9
125	0.85

Appendix C - Interface Columns Tables

The User Interface forms present dropdown lists for data selection and modification, and they change the types of comparative operators and input controls depending on the selections. For example, on the *Polygon Selection* form, if the *irrigId* attribute is selected in one of the additional conditions boxes, then the choice of operators changes to *is one of* and *is NOT one of* and the associated value selection control becomes a multi-select dropdown list that allows for one or more items to be selected. On the other hand, if the selected attribute is *elevation*, then the operators show as *greater than* and *less than* symbols and the value box becomes a simple textbox. An *is one of* operator wouldn't make sense for specifying an elevation test, nor would a list of individual elevation values for the selection.

The columns that appear in the selection boxes, the types of operators used, and the form that the value control takes are controlled by a pair of tables in the application database. These tables are described here more for completeness than under the expectation that users would modify them. Simple changes to accommodate new attributes used strictly for geographic area selection could probably be made without any internal code modifications. There's a good chance, however, that any significant changes would involve some alteration in the code or table structures, etc.

interface_main_selection_columns

Used to tell the interface forms what columns can be used for selecting polygons for modeling.

display_name
- name that shows in the selection box on the interface form

column_name
- corresponding column name in the *Polygons* table

interface_main_selection_columns

display_name	column_name
Water Purveyor	watpurvid
Local Government	locgovid
< all >	
Water Source (License, Ground, Purveyor)	lgpCode
Subbasin	subbasinId
Specific Aquifer	aquiferLab
Aquifer Type	aquiferTyp
Report Zone	reportZone

interface_update_columns

Lists the columns that appear for selection or modification on the *Land Use and Modeling Parameter Changes* form, which operators should be presented and how the value controls should behave.

column_name
- name of the column as it appears in the *Polygons* table

clause
- the SQL clause where the attribute can be used:
  set – can appear only in the SET clause
  where – can appear only in the WHERE clause
  either – can appear in either the SET or WHERE clauses

where_selection_type
- for attributes in a WHERE clause, the operator(s) that should be displayed:
  single select – *equals* (=) and not *equals* (<>)

multi select – *is one of* and *is NOT one of*
number inequality – *greater than* (>) and *less than* (<)

where_data_type

- for attributes in a WHERE clause
  string – add quotes around the value
  number – leave unquoted

interface_update_columns

column_name	clause	where_selection_type	where_data_type
cropId	either	multi select	string
irrigId	either	multi select	string
soilId	either	multi select	string
irrigUsed	either	single select	string
slope	where	number inequality	number
aspectClass	where	number inequality	number
elevation	where	number inequality	number
latitude	where	number inequality	number
inALR	where	single select	string
sewerSept	either	multi select	string

Appendix D - Adding a Climate Model

Adding a new climate model to the application requires the following:

- the data files, in the same ESRI ascii grid format as the current models, have to be loaded onto the system and their locations recorded in the *climate_sources* table in the *iwdm_climate_sources* database in the *climate_databases* location

- the climate file set has to be pre-processed to calculate indices including the first and last frost days, the start and end of the Growing Degree Day accumulations for base temperatures 5 and 10, and the TSUM threshold days; these statistics get placed in yearly tables in a database named for the climate model in the *climate_databases* location

Although it hasn't been given a User Interface, the utility module *add_climate_model* can be used to do both of the tasks above as long as the standard directory structure has been used to store the new climate model. For example:

```
f:\iwdm_climate_sources
    \bonaparte
        \cgcm2.a2
            \1960
                \BP_m1_d25_1960.asc
                \TN_1960_m1_d25.asc
                \TX_1960_m1_d25.asc
```

The utility accepts the path to the folder just above the model name and the model name as two separate parameters; it uses the model name for updating the climate_sources table and for creating the new climate database to hold the calculated indices. It uses the concatenation of the path and model name to obtain a list of the years to process. The routine parses the file name to determine the month and day; the only formats that are currently supported are those listed in the example above where the precipitation files start with BP and have the month, day and year following, and the minimum (TN) and maximum (TX) files store the year first followed by month and day. Other naming schemes would require code modifications.

To run the utility against a new climate model stored in the structure outlined above:

1. Open the application database in the mode that bypasses the startup form: hold the SHIFT key down while pressing the Enter key or clicking on OK after typing the application password
2. Select the Modules object from the Objects list
3. Open the *add_climate_model* in Design mode (or just double-click it)
4. Change the path and model name in the Call line in the *add_climate_model* subroutine; for example:

   ```
   Call add_climate_sources("f:\iwdm_climate_sources\bonaparte\", "cgcm2.a2")
   ```

5. Select Run or press F5

It takes several hours to complete the pre-processing for a single climate model.

Appendix E - Output Statistics and Indices

This appendix describes the raw outputs of the Agriculture Water Demand Model. Many of these indices are geared towards a research use – they are available as data tables, but don't appear in any of the formatted summary reports. Others do show in the summaries, but generally as part of rollup into a given reporting period.

Annual Climate Cell Indices

These are values that can be calculated on an annual basis for each climate cell within each climate model. Once derived, they don't change with attributes such as crop type or day of the year, and as such, they are developed as part of the data preparation stage rather than during a run of the IWD model for a particular scenario. These tables are currently stored one per year in a one-per-climate-model database (i.e. table *1967* in database *cgcm3.a2.mdb*). These databases live in the folder identified in the application configuration table (*iwdm_configuration*) as the *climate_databases_location;* by default, this is the *climate_databases* subdirectory in the modeling area's branch.

Table Structure

Column Name	MS Access Data Type
year	Integer
climateID	Text (10)
last_frost	Integer
first_frost	Integer
killing_frost	Integer
frost_free_days	Integer
growing_degree_days_base5_start	Integer
growing_degree_days_base5_end	Integer
growing_degree_days_base5	Double
growing_degree_days_base10_start	Integer
growing_degree_days_base10_end	Integer
growing_degree_days_base10	Double
corn_heat_units	Single
total_precipitation	Single
total_et0	Single
corn_start	Integer
silage_corn_end	Integer
tsum200_day	Integer
tsum300_day	Integer
tsum400_day	Integer
tsum450_day	Integer
tsum500_day	Integer
tsum600_day	Integer
absolute_tmin	Single
absolute_tmin_day	Integer
absolute_tmax	Single
absolute_tmax_day	Integer

Column Meanings

year
    modeling year

climateId
    climate cell identifier; 01870023 corresponds to row 187, column 23 in the climate grid

last_frost
    julian day of the last temperature <= 0 falling between days 1 and 180

first_frost
day of the first temperature <= 0 falling between days 240 and 365 (366)

killing_frost
day of the first temperature <= -2 after the *first_frost* day

frost_free_days
number of frost free days calculated as *firstFrost – lastFrost – 1*

growing_degree_days_base5_start
day corresponding to the start of the Growing Degree Days 5 season

growing_degree_days_base5_end
end of the GDD5 season

growing_degree_days_base5
accumulation of GDD5 heat units (within GDD5 season)

growing_degree_days_base10_start, growing_degree_days_base10_end, growing_degree_days_base10
as for GDD5 values

corn_heat_units
corn heat units accumulation

total_precipitation
total accumulation of precipitation for the year

total_et0
total accumulation of potential evapotranspiration for the year

corn_start
start of the corn growing season

silage_corn_end
end of the growing season for silage corn

tsum200_day
julian day where the TSUM200 accumulation is reached (sum of positive mean temperatures >= 200)

tsum300_day, tsum400_day, tsum450_day, tsum500_day, tsum600_day
as for tsum200_day

absolute_tmin
minimum temperature for the year

absolute_tmin_day
julian day on which the absolute minimum temperature occurred

absolute_tmax
maximum temperature for the year

absolute_tmax_day
julian day on which the maximum temperature occurred

Annual Crop Indices

The Crop Annuals table (*crop_annuals* in the Case Study database) contains indices that are annual in nature, but differ for each crop and climate cell. The growing season definitions differ between crops and are often based on climate cell indices such as the TSUM or GDD thresholds.

Table Structure

Column Name	MS Access Data Type
year	Integer
cropId	Text(20)
climateID	Text (10)
season_start	Integer
season_end	Integer
season_length	Integer

Column Meanings

year
: modeling year

cropId
: crop identifier as per the Landuse source

climateId
: climate cell identifier

season_start
: julian day corresponding to the start of the crop's growing season

season_end
: day corresponding to the end of growing season day

season_length
: growing season length calculated as *season_end – season_start*

Daily Polygon Statistics

The Polygon Dailies table (*polygon_dailies* in the Case Study database) forms the basis of the summary reports and data extracts used for populating other databases. Since it contains a row for each combination of crop, soil type, irrigation type and climate cell for each day of the crop's growing season, the table can be large; a 10-year modeling run of the full Okanagan Valley currently generates approximately 23 million rows. In order to accommodate those 10-year runs, a space-saving technique is used whereby each crop+climate+soil+irrigation type combination is assigned a sequential number which is used as the unique identifier in the polygon dailies table; this is the *linkKey* attribute. The linkKey is an index into the *linkage_keys* table, which then carries the associated cropId, climateId, soilId and irrigId values.

Table Structure

Column Name	MS Access Data Type
year	Integer
julianDay	Integer
linkKey	Long Integer
SMD	Single
ET0	Single
EP	Single

Kc	Single
ETc	Single
CMD	Single
storedMoisture	Single
CMDa	Single
CWR	Single
IR	Single
IWDperc	Single
IWD	Single
weekNumber	Integer
monthNumber	Integer

Column Meanings

year
modeling year

julianDay
julian day of the year

linkKey
identifier linking each row to the cropId+climateId+soilId+irrigId values in the *linkage_keys* table

SMD
beginning of season soil moisture deficit

ET0
general evapotranspiration value

EP
effective precipitation

Kc
crop coefficient

ETc
crop evapotranspiration

CMD
climate moisture deficit

storedMoisture
moisture stored in the soil; used to offset climate moisture deficit

CMDa
adjusted climate moisture deficit (adjusted by storedMoisture)

CWR
crop water requirement (not affected by irrigation efficiency)

IR
irrigation requirement (CWR taking efficiency into account)

IWDperc
component of the irrigation water demand lost to deep percolation

IWD
total irrigation water demand (IR + IWDperc)

weekNumber
week of the year using one of the week definitions (e.g. obwb)

monthNumber
month number (1 – 12)

Weekly, Monthly, Annual and Total Polygon Statistics
For convenience for summary reporting, the model automatically creates rollup tables corresponding to weekly, monthly, and annual periods, and grand totals (a single summary line for all modeled years). The tables carry a subset of the daily attributes, summed to the corresponding period. For example, the *polygon_weeklies* table has a column for ET0; this is the sum of the daily ET0 values for each week.

Appendix F – Water Demand Model RFP

The Request for Proposal for development of the Agriculture Water Demand Model presents much of the background information, terms, algorithms, and rationale for the methodology used in the model, and it's included here to provide extra detail.

Things have evolved and changed, however, and the descriptions in the rest of this document provide the correct version of the methodology as implemented.

Request for Proposal

Project Title:	*Development of an Agriculture Water Demand Model for the Okanagan*
Vendor:	*British Columbia Ministry of Agriculture and Lands* *British Columbia Agriculture Council*
Issue date:	*March 19th, 2007*
Closing Date & Time:	*April 4th, 2007 at 14:00 hour*

Receipt Confirmation Form

To ensure that you receive any updates or additional information being made available to prospective bidders, please complete the Receipt Confirmation Form (**Appendix A**) and fax it as per the instructions on the form as soon as possible. The form will also be used to establish an interview schedule with bidders to review the project development and deliverables.

Contacts for More Information

***Ted van der Gulik**, P. Eng.* *Senior Engineer* *B.C. Ministry of Agriculture and Lands* *Resource Management Branch* *Email: Ted.vanderGulik@gov.bc.ca* *Phone: (604) 556-3112*	***Jennie Aikman*** *Land Resource Specialist* *B.C. Ministry of Agriculture and Lands* *Resource Management Branch* *Email: Jennie.Aikman@gov.bc.ca* *Phone: (604) 556-3110*	***Denise Neilsen**, Ph.D.* *Research Scientist* *Agriculture and Agri-Food Canada* *Pacific Agri-Food Research Centre* *Email: NeilsenD@agr.gc.ca* *Phone: (250) 494-6417*

Delivery of Proposals

Proposal envelopes should be clearly marked with the name and address of the Proponent and the project title. Three complete hard copies and one electronic copy on diskette or CD must be **delivered by hand or courier** to:

Resource Management Branch
B.C. Ministry of Agriculture and Lands
1767 Angus Campbell Road
Abbotsford, B.C. V3G 2M3
Attention: Ted van der Gulik, P. Eng.

NOTE:

Proposals received at this address after 14:00 hrs on April 4th, 2007 will be returned unopened.

Development of an Agriculture Water Demand Model

1. Background

An Okanagan Basin Water Strategy was initiated by Land and Water British Columbia (LWBC) in 2004 in response to significant pressures being exerted on the water resources in the basin. Rapid population growth, drought conditions from climate change, and the overall increased demand for water are driving this trend. Several recent studies have supported the scenario of a pending water crisis as Okanagan water resources are expected to be fully allocated in the next 15 – 20 years.

Climate change scenarios developed by UBC and the Pacific Agri-Food Research Centre (PARC) in Summerland predict that winter snow packs will decrease as the climate warms and the snow level moves higher up the mountains. Opportunities for storage will be limited if moisture is changed from snow to rainfall and the timing of precipitation also changes. Further, agricultural water demands are expected to increase as climate change creates hotter summers and longer growing seasons.

The first phase of the LWBC project was to revisit a comprehensive Okanagan Basin study that was completed in 1974. Many of the action items identified in the 1974 study have not been implemented, which has been of concern to water managers in the Okanagan. LWBC's review included conducting an assessment of the supply and demand data available, identifying information gaps and facilitating a process that would establish clear expectations and outcomes for Phase 2. Phase 1 was completed in 2005.

Phase 2 of the project, now being led by the Ministry of Environment, will be to initiate a water balance strategy that is aimed at providing a detailed assessment of water supply and demand in the entire Okanagan Basin. Currently, the agricultural water demand is estimated to be 70 -75% of the water use in the basin.

The agricultural water demand model being developed under this Request for Proposal will provide the demand information required for the Okanagan Basin Water Balance study. To date the agricultural demand project has unified all of the cadastral information for the Okanagan Basin, collected 85% of the agricultural land use information and developed a climate data layer for the entire basin. The model must be able to calculate current and future agricultural water demand for each agricultural property in the basin using land use information, soils and climate data. An explanation of the data sets and model requirements are explained further in this Request for Proposal.

2. The Task

A consultant is to be retained to develop a model and graphical user interface that will calculate agriculture water demand using the parameters outlined in this proposal. The model must be able to calculate and store data in MS Access and display the information in a GIS system using ArcGis or Arcinfo. Different scenarios based on crop type, geographic location, irrigation system use and climatic data must be able to be run and stored. The model will use a dataset that will be referred to as ClimateID, CadastreID, PolygonID ,CropID, IrrigID and SoilID.

For ease of reference tasks are identified by number. A list of key tasks, deliverables and interaction requirements with the project steering committee is provided in sections 11 and 12 of this proposal.

3. ClimateID

The agricultural water demand is dependent on climate, crop, irrigation system and soil type. The Okanagan region's climate is quite diverse. The climate generally gets cooler and wetter as you move from south to north and as the elevation increases. Climate data has been developed to calculate agricultural water demand on a daily basis. Using the climate data, the model will need to calculate evapotranspiration on a daily basis so that various scenarios such as changes to the length of growing season can be used to calculate crop water demand.

The climate data set has been developed by using existing data from climate stations in and around the Okanagan Basin from 1961-2006. This climate data set was then extrapolated to provide a climate data layer for the entire Okanagan Basin on a 500 m x 500 m grid.

Figure 1 shows a map of existing climate stations that were used to determine the climate coverage.

Climate change scenarios have also been developed until the year 2100 with precipitation, minimum and maximum temperature data stored for each grid cell and for each Julian day.

The ClimateID is a Raster GIS-based dataset. The ClimateID grid cells will be identified by numbers ranging from C1 to approximately C25000 and will cover the entire Okanagan Basin. The attributes that will be attached to each ClimateID will include:

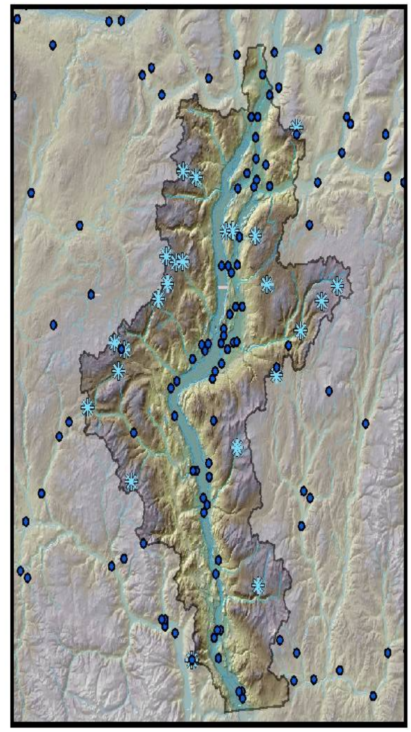


Figure 1 Okanagan Climate Stations

- Latitude
- Longitude
- Elevation
- Aspect
- Slope
- Precipitation, MaxT, and MinT

A climate database has been developed that will provide daily MinT, MaxT, MeanT and Precip for each day of the year from 1961 until 2006. In addition daily climate change data (precip, Tmax, Tmin) until the year 2100 is included in the database.

3.1 The model must be able to retrieve selected data from the climate database and assign the daily attributes to the ClimateID. It is expected that this must be able to be done on a monthly or yearly basis. The ClimateID with the selected data must be able to be stored as a unique data set and identified as a case study. This data set will include the original attributes attached to the ClimateID as well as the additional attributes of Year, Julian day, MaxT, MinT, MeanT and Precip.

3.2 There are a number of indices that must be calculated and stored with the ClimateID. The model will require a graphical user interface (GUI) that will allow the user to select the agricultural indices to be calculated. The model user must also be able to select the area in the basin for which the indices need to be calculated. The agricultural areas could be identified by the CadastreID. Forested areas may be identified by elevation.

3.3 The model must allow for the selection of the indices separately. Not all indices may be required for each case study.

3.4 The indices that need to be selected, calculated and stored with the ClimateID are:

- Evapotranspiration – (ETo) The algorithms for Eto are shown in Appendix C
- Effective Precipitation (EP) – Appendix D
- Frost Free Days – Appendix D
- Growing Degree Days (base 5 and base 10) – Appendix D
- Corn Heat Units – Appendix D
- First Frost – Appendix D

3.5 There are a number of climatic indices that are crop based that must be calculated and stored with the PolygonID. These are:

- Growing season length – Appendix D
- Beginning and end of the growing season – Appendix D.

The model must calculate the length of the growing season using the Climate ID and CropID. The CropID will be an attribute of the PolygonID. The beginning and end of the growing season must also be determined and recorded using Julian day. The calculated beginning and end of the growing season and growing season length will be stored with the PolygonID. The algorithms are shown in Appendix D.

3.6 The model must calculate effective precipitation and store the information with the ClimateID. The algorithm for effective precipitation is shown in Appendix D.

3.7 The model must be flexible to allow for additional indices to be added at a later date.

Figure 2 graphically shows the data the variance in climate data for the Okanagan that can be expected for any day.

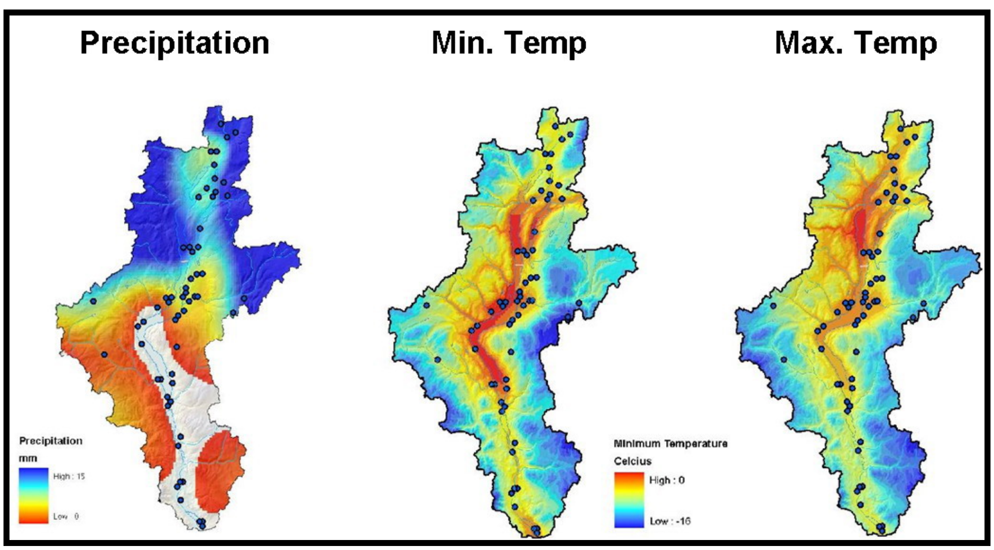


Figure 2 Climate Data

4. CadastreID

A unified cadastre has been developed for the Okanagan Basin using data provided by the Regional Districts and other local governments. A land use survey was completed on a parcel basis for all agricultural lands in the Okanagan Basin. The information collected included crop, irrigation system type and whether the property was irrigated or not. The coding used for the crop and irrigation system are shown in Appendix E and F respectively.

All cadastre units are identified using a unique number starting with an “L”. (i.e L34567). For the model to work effectively the Okanagan Basin has been divided into smaller areas. Water use can be calculated for each of these areas and then totalled if desired to obtain the overall water use in the basin.

4.1 The Okanagan Basin must be divided into subareas identified as SubasinID (there are approximately 79 sub-basins identified), WatpurvID (approximately 35 sub units) and LocgovID (there are 4 regional districts). These units, based on sub-basin, water purveyor and local government boundaries provided by the proponent will be used for assembling outputs and directing the model on the areas to calculate water use. Each of the units will be assembled using the CadastreID. Appendix H lists the 79 sub-basins that will be used for this project.

4.2 The model will calculate water use for each PolygonID and total the polygons to determine water use for each CadastreID.

4.3 The water use for each CadastreID will be compiled for each basin subunit (estimated to be 70) and then compile the subunits to determine the basin water use.

5. PolygonID

The smallest unit for which water use will be calculated will be the polygons within each CadastreID. A polygon is determined by a change in land use or irrigation system within a cadastre. The intersection of soil boundaries and the climate grid creates additional polygons within the cadastre. **Figure 3** shows how polygons are generated based on land use in the Okanagan Basin.

Figure 3. GIS Land Use

Figure 4 shows how the land use information is divided into additional polygons using the soil and climate grid information. The climate grid, soil boundary, cadastre and land use information polygons are all used to calculate water use for each property. The water use for each separate polygon must be calculated and added together to determine the water requirement for each cadastral unit. All PolygonID's are identified using a unique number starting with a "P". (i.e P100345).

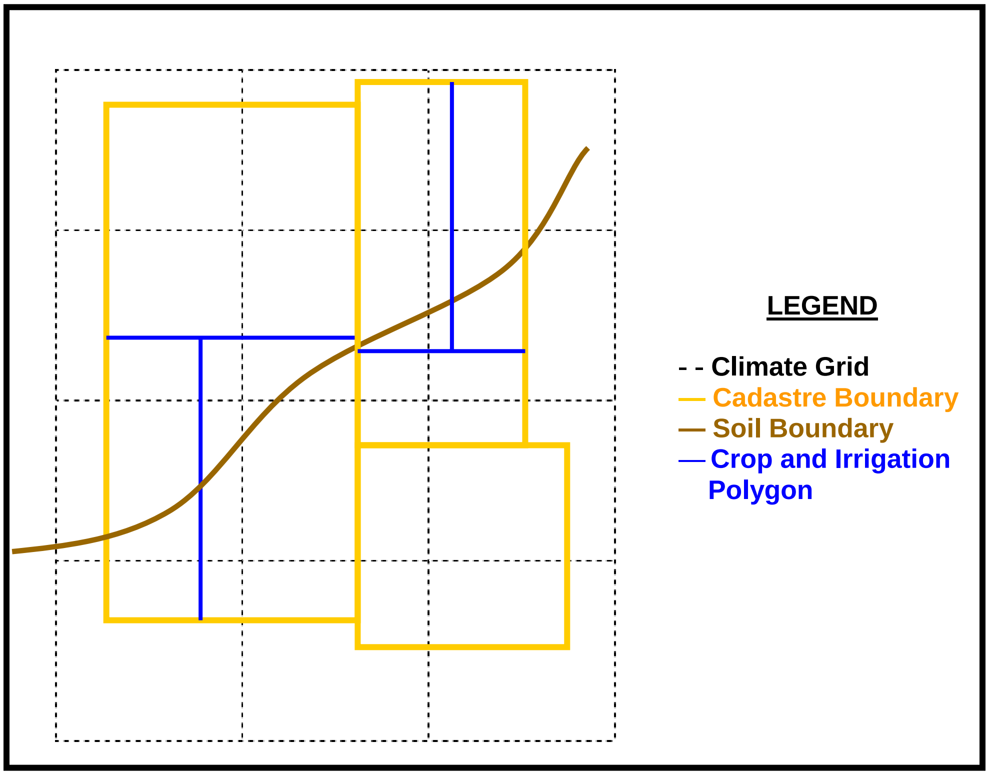


Figure 4 GIS Model Graphic

5.1 PolygonID's have been assigned to polygons that have been developed using the land use and cadastre information. PolygonID's will have to be assigned to all new polygons that are generated by the soil boundaries and climate grid.

5.2 PolygonID will contain the attributes CropID, IrrigationID and the climatic indices beginning and end of the growing season and growing season length. The crop indices Availability Coefficient and Crop Coefficient are also an attribute of the PolygonID since these values will change based on climate and crop throughout the valley. The climate and crop indices that are required to be calculated are shown in Appendix D.

5.3 Water use will be calculated using the PolygonID. The model must be able to report water use by polygon and a compiled water use for CadastreID, SubasinID, WatpurvID and LocgovID.

6. CropID

CropID is an attribute of the PolygonID. The crop information (observed during 2005 – 2007) 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 will also be used to calculate the growing season length and the beginning and end of the growing season. See Appendix D for equations.

The attributes for CropID are shown in Appendix E and include rooting depth, availability coefficient and a drip factor. The drip factor is used in the water use calculation for polygons where drip irrigation systems are used.

6.1 The model must calculate the availability coefficient using the CropID and the equation shown in Appendix D and assign the value to the PolygonID. The availability coefficient is used with the IrrigID to determine the number of irrigation events that are estimate for each irrigation season for each PolygonID.

6.2 The model must also determine the crop coefficient using the CropID and the equations for each crop in Appendix D. The crop coefficient will be calculated and stored with the PolygonID.

6.3 The model must allow for the selection of future cropping scenarios. The scenario will be stored with the PolygonID and stored as a case study. Cropping scenarios will be selected by using ClimateID, CropID, SoilID and PolygonID.

6.4 Cropping scenarios must be able to be determined for the SubasinID, WaterpurvID and the LocgovID.

6.5 The list of crops may not be complete. The model must have the flexibility to have additional crops added at a later date.

7. IrrigID

The IrrigID is an attribute of the PolygonID. The irrigation information has been collected and stored as observed during 2005 – 2007 with the land use data. Appendix F provides a list of the data collected and the IrrigID that will be used in the model. The IrrigID will be an attribute of the PolygonID as each polygon will have a unique IrrigID. The IrrigID has an irrigation efficiency listed as an attribute.

Two of the IrrigID, Overtreedrip and Overtreemicro are polygons that have two systems in place. In this case the efficiencies used in the model are the drip and microsprinkler efficiencies. These two codes can be used to estimate the amount of water used for crop cooling purposes.

7.1 The model must allow for the selection of future irrigation scenarios and to have the information stored as a case study. Irrigation scenarios will be selected by using CropId and PolygonId. (i.e. convert all apple, cherry crops to drip irrigation)

7.2 Irrigation case studies must be able to be determined by SubasinID, WatpurvID and LocgovID. The IrrigID scenarios will be stored as a case study with the PolygonID.

8. SoilID

The soils layer provided is from CAPAMP data provided by the Ministry of Energy, Mines and Petroleum Resources. Appendix G provides information on the SoilID. The attributes attached to the SoilID is the Available Water Storage Capacity (AWSC).

8.1 Soil water storage at the beginning of the season must be calculated or a number added for use by the model. The term used in this model will be Soil Moisture Deficit (SMD). The formula for calculating SMB is shown in section 9.

8.2 The Maximum Soil Water Deficit (MSWD) must be calculated to determine the parameters for the algorithm that is used to determine the Irrigation Requirement (IR). The MSWD is calculated using the same formula as the SMD and is shown in section 9.

8.3 An analysis of the ability of the soil profile to capture rainfall events.

8.4 The model must be able to calculate the theoretical water use for lands in the ALR that are currently not irrigated based on SoilID, ClimateID and PolygonID.

9. Irrigation Water Demand Equation

The Irrigation Water Demand (IWD) is calculated for each polygon. The polygons are then summed to determine the IWD for each cadastre. The cadastre are summed to determine IWD for the SubasinID, WatpurvID and LocgovID.

9.1 The first step is to calculate the Evapotranspiration Rate for each crop (ETc). The Etc is calculated using ETo and the crop coefficient (Kc) as follows:

ETc = ETo x Kc

The ETc is stored with the PolygonID.

9.2 The second step is to calculate the Climatic Moisture Deficit (CMD). The CMD is calculated from the Crop Evapotranspiration (Etc) and the Effective Precipitation (EP). The formula for EP is provided in Appendix D. The formula to calculate CMD is:

CMD = ETc – EP

The CMD is stored with the PolygonID. The CMD is calculated daily but summarized for the length of the growing season (or a specified time period as selected for the case study) that has been determined for the crop that is resident on the polygon.

9.3 The third step is to calculate the Irrigation Requirement (IR). The irrigation requirement uses the CMD and also takes into account the soil type and the Soil Moisture Deficit (SMD) at the beginning of the growing season. The SMD is a function of the crop rooting depth (RD) from Appendix E, the Available Water Storage Capacity (AWSC) from Appendix G, and the crop availability coefficient (AC) from Appendix E or it can be calculated from Appendix D. The formula to calculate the SMD is:

SMD = RD x AWSC x AC (to determine potential soil storage at the beginning of the growing season)

MSWD = RD x AWSC x AC (for use in determining parameters used in the IR algorithm)

The formula to calculate the Irrigation Requirement (IR) is:

$$IR = a_0 + a_1 \times CMD + a_2 \times (CMD)^2 + SMD$$

The parameters a_0, a_1, and a_2 can be found in Appendix G and are based on the MSWD calculated for each polygon. The SMD and IR are stored with the PolygonID.

9.4 The Irrigation Water Demand (IWD) is determined from IR, a factor that adjusts area irrigated by a drip system (Drip Irrigation Factor (Df)) and the Irrigation System Efficiency (Ie). The Drip Factor (Df) is only used when a drip irrigation system is used in the polygon. The Df defaulsts to 1.0 if a drip irrigation system is not used. The IWD is calculated and assigned to the PolygonID daily using the following formula:

$$IWD = \frac{IR \times Df}{Ie}$$

The IWD is stored with the PolygonID.

9.5 Calculation Scenarios

- The model must calculate Irrigation Water Demand (IWD) for specified time periods (i.e. week, month or season)
- IWD must be able to be calculated by SubasinID, WatpurvID and LocgovID

10. Meter Data

Many of the water purveyors in the Okanagan Basin are in the process of installing meters for all agricultural connections. The model provides an opportunity for actual water used data to be compared to the estimated water use as calculated by the model.

10.1 The model must be able to import meter attributes from the water purveyor's database with a unique identifier that links the meter to the CadastreID.

10.2 The model must have the ability to provide monthly and annual water use as measured by the meter for each CadastreID within each of the WatpurvID that is using meters. Meter data does not have to be linked under this project but the ability to link meter information must be built into the model.

10.3 The model must allow for a comparison of actual water used data with the estimated water use as calculated by the model.

10.4 The model must be able to provide a water use report that can be sent to individual producers. The report must provide a comparison of the producer's water use with other producers that are growing similar crops on similar soils and using the same irrigation system. A sample water use report is shown in Appendix I.

10.5 A dataset containing all calculated indices, climate and land use information for Vernon and Summerland must be provided to allow for the model to calculate IWD and deliver water use reports to a web based system being developed for their water management programs.

11. Project Summary

The items listed under the previous sections provide a list of requirements for the model. The model must also be easy to use and the selection of case studies and scenarios intuitive.

11.1 The model will calculate water use by SubasinID and total the entire basin from the SubasinID information. A summary report that allows for the checking of results prior to the program compiling all information must be available.

11.2 A graphical user inferface (GUI) must be developed that allows the user to select appropriate information, enable calculations and store scenarios for additional operations.

11.3 A GUI is required for selecting the region for which a case study is to be done. Users must be able to run the model for the entire basin, SubasinID, WatpurvID or LocgovID.

11.4 A GUI to execute all of the calculations related to the ClimateID and store as a case study.

11.5 A GUI to execute all of the calculations related to the PolygonID and store as a case study.

11.6 A GUI that will calculate selected agricultural indices and store as a case study.

11.7 A GUI that will allow for the retrieval of appropriate case studies and calculate water use for cropping and irrigation system scenarios that have been selected.

11.8 A GUI that allows for the calculation of basin water use for properties that are currently not irrigated.

11.9 Development of a water use report using meter data and model output as explained in section 10.

11.10 The outputs required from the model are:

a. Display Irrigation Water Demand (IWD) for each property in mm of depth and store with CadastreID.
b. Calculate IWD for specified time periods (i.e. week, month or growing season)
c. Generate a report that summarizes water use in acre-ft or cubic decameters for the entire basin, SubasinID, WatpurvID or LocgovID.
d. Display IWD information for each property (mm) in GIS for the entire basin, SubasinID, WatpurvID or LocgovID.
e. Generate a report that summarizes IWD by crop type for the entire basin, SubasinID, WatpurvID or LocgovID.
f. The model must be able to include regions that are currently not irrigated and add theoretical water use for these regions as a scenario.

12. Project Reporting

A project steering committee will oversee the development of the model. The project steering committee will verify and provide the algorithms required to run the model. The consultant's task is to develop the model by integrating all of the algorithms to deliver the outputs requested and to develop a graphical user interface (GUI) that will allow the model to be run by technical staff in the Ministry of Agriculture and Lands and Agriculture and Agri-food Canada.

The project will require on going reporting from the consultant to the project manager. It is anticipated that at least four meetings with the steering committee are required during model development. The suggested stages for meetings to allow for interim testing and incremental development are:

12.1 Meeting 1: Initial meeting with project steering committee to scope project.

12.2 Meeting 2: Verification that algorithms are generating the correct answers for selected polygons. Provide results for all calculations from Beta-testing of the model to the steering committee. Identify debugging and other requirements to ensure the model provides correct results and performs output expectations. Preliminary scoping of the GUI that will be required to operate the model.

12.3 Meeting 3: Calculation of Irrigation Water Demand (IWD) for current climate data on one sub-basin to verify model is working correctly and providing correct information. A review of GUI development to date and approval of the final GUI interface.

12.4 Meeting 4: Review of model function and outputs. Identification of remaining tasks prior to turning the model over to the Project Steering Committee.

Additional meetings with the Steering Committee and/or Project Manager can be held at the request of the consultant.

13. Proposal Evaluation

This section details all of the mandatory and desirable criteria against which submissions will be evaluated. Consultants should ensure that they fully respond to all criteria in order to receive full consideration during evaluation.

Project: Agriculture Water Demand Model Development

Contract Time Frame: The contract must be completed by February 28th, 2008.

Proposals: Submissions must include:

- A breakdown of costs for various components of model development as outlined in this RFP. Similar tasks can be grouped as required to provide a cost estimate. Section 11 can be used as a guide to group tasks and provide a cost estimate.
- A total cost estimate of proposed fees and expenses. Hourly and daily rates are required for each person working on the project.
- Identification of any support staff or required sub-contractors (e.g. administrative support).
- Brief description of strengths that the consultant will bring to the project that will support successful completion of the project.
- Time frame for contract completion.
- Two references who can verify your qualifications and experience
- An example of a project that was completed by your firm that is of a similar nature.

Suitability Interview: The complexity of the development of this model will require the bidder to attend an interview with the selection panel. The intent of the interview will be to review the tasks requested and to ensure that there is a mutual understanding of the product to be delivered, timelines and cost of work to be completed. Bidders that are deemed to be acceptable will be interviewed in early April. Not all bidders will necessarily be interviewed. Selection of the consultant will be made after all interviews have been completed.

Travel Expenses:
Reimbursement of travel expenses will be based on receipts and information provided in **Appendix B.**

Closing Date & Time: The proposal must be received at the closing location before April 4th, 2007 14:00 hrs. Note: Proposals received after this date and time will be returned unopened.

The proposals must be in English and must not be sent by mail, facsimile or e-mail.

Three hard copies of the proposal and one copy on diskette or CD must be submitted with one cover page or cover letter signed by the contractor.

Appendix A: Receipt Confirmation Form

Closing Date & Time: Proposal must be received before **2:00 PM Pacific Time on April 4th, 2007**

For further distributed information about this Request for Proposals, please return this form by fax as soon as possible to:

Ted van der Gulik, P. Eng.
Resource Management Branch, Ministry of Agriculture and Lands
Fax: (604-556-3099)
Email: Ted.vandergulik@gov.bc.ca

COMPANY: ____________________

STREET ADDRESS: ____________________

CITY: ____________ COUNTRY: ____________

MAILING ADDRESS, IF DIFFERENT: ____________________

FAX NUMBER (___) ____________ PHONE NUMBER (___) ____________

CONTACT PERSON: ____________________

TITLE: ____________________

EMAIL: ____________________

APPENDIX B

Travel Expenses and Accommodation Instructions for Contractors

General:
The most economic travel arrangements should be used consistent with the time available to conduct the business.

Travel expenses will be reimbursed where the invoice is supported by a statement showing the accumulation of expenses for the trip under the various categories and to which original receipts, as required, are attached.

Private Car Transportation:
Effective April 16, 2006, an allowance of 47¢ per kilometre for the use of the contractor's private vehicle may be claimed. It is intended to cover costs of gas and maintenance.

Reimbursement for parking essential to the business may be claimed. Receipts are required, while parking machine tickets marked with the total paid and signed by the claimant are acceptable.
Owners are responsible for ensuring they have adequate insurance to cover business use.

Public Transportation:
Receipts are required for reimbursement of actual expenses incurred through the use of buses, airlines (most economical fare), ferries, taxis, rental cars and tolls, except where the daily charges for bus or taxi are less than $20.00.

Meal Allowance:
Receipts for meals are required if they are to be reimbursed.

Accommodation:
In making a hotel selection for your travel:

- Select the most cost effective hotel that meets your business requirements considering the basic room cost and any supplementary costs for internet access, parking or other costs.
- Where staying at a bed and breakfast properties and a full breakfast is included in the base rate then your reimbursement claim should not include a breakfast component.

You will be reimbursed for the full amount of the hotel's base rate, plus other applicable business expenses, e.g., parking, internet access.

Contractors must ensure that they only claim for authorized contract staff, supported by the "number in party" identified on the appropriate lodging receipt.

Original receipts and proof of payment are required.

APPENDIX C

Procedure for calculating ET_o using FAO Penman-Monteith with only minimum and maximum temperature

Data Required:

Elevation, metres [m]
Latitude, degrees [^{o}]
Minimum Temperature, degree Celsius [°C]
Maximum Temperature, degree Celsius [°C]
Classification as Coastal or Interior
Classification as Arid or Humid
Julian day

Data assumed or constants:

Wind speed	2 m/s
Albedo or canopy reflection coefficient, α	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

Procedure:

1. Calculate mean air temperature, T [°C]

$$T = \left(\frac{T_{\min} + T_{\max}}{2} \right)$$

2. Calculate actual vapour pressure, e_a [kPa]
Use minimum temperature and adjustment factor depending on climate classification humid or semi-arid.

$$e_a = 0.6108 \ \exp\left[\frac{17.27\ (T_{\min} - K_o)}{(T_{\min} - K_o) + 237.3} \right]$$

where:
K_o = 0 °C for humid and sub-humid climates
K_o = 2 °C for arid and semi-arid climates

Stations are classified as coastal and interior, interior stations are considered semi-arid, while coastal stations are considered to be humid.

3. Calculate saturated vapour pressure for T_{max}, $e_{(Tmax)}$ [kPa]

$$e_{(T_{\max})} = 0.6108 \ \exp\left[\frac{17.27\ T_{\max}}{T_{\max} + 237.3} \right]$$

4. Calculate saturated vapour pressure for T_{min}, $e_{(Tmin)}$ [kPa]

$$e_{(T_{min})} = 0.6108 \ \exp\left[\frac{17.27\, T_{min}}{T_{min} + 237.3}\right]$$

5. Calculate saturated vapour pressure, e_s [kPa]

$$e_s = \left(\frac{e_{(T_{min})} + e_{(T_{max})}}{2}\right)$$

where:

$e_{(Tmax)}$ = Step 3
$e_{(Tmin)}$ = Step 4

6. Calculate inverse relative distance Earth-Sun, d_r [rad]

$$d_r = 1 + 0.033 \ \cos\left(\frac{2\,\pi}{365}\, J\right)$$

where:

J = Julian day

7. Convert latitude to radians, φ [rad]

$$\varphi(rad) = \frac{\pi}{180}\, lat(°)$$

where:

lat = latitude of station in degrees

8. Calculate solar declination, δ [rad]

$$\delta = 0.409 \sin\left(\frac{2\,\pi}{365}\, J - 1.39\right)$$

where:

J = Julian day

9. Calculate sunset hour angle, ω_s [rad]

$$\omega_s = \arccos\left[-\tan(\varphi)\,\tan(\delta)\right]$$

where:

δ = Step 7
φ = Step 8

10. Calculate extraterrestrial radiation, R_a [MJm^{-2} day^{-1}]

$$R_a = \frac{24 \times 60}{\pi} G_{sc}\, d_r \left[\omega_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)\right]$$

where:

d_r = Step 6
14. = Step 7
15. = Step 8

ω_s = Step 9
G_{sc} = solar constant = 0.082 $MJm^{-2}\ min^{-1}$

11. Calculate clear sky solar radiation, R_{so} [$MJm^{-2}\ day^{-1}$]

$$R_{so} = \left(0.75 + 2\times10^{-5} z\right) R_a$$

where:
Z = elevation of climate station above sea level [m]
R_a = Step 10

12. Calculate solar radiation, R_s [$MJm^{-2}\ day^{-1}$]
Use adjustment factor K_{Rs} depending on station location, coastal or interior

$$R_s = K_{Rs}\ \sqrt{(T_{\max} - T_{\min})}\ R_a$$

where:
K_{Rs} = 0.16 for interior locations
K_{Rs} = 0.19 for coastal locations

13. Calculate net longwave radiation, R_{nl} [$MJm^{-2}\ day^{-1}$]

$$R_{nl} = \sigma\ \frac{(T_{\max} + 237.15)^4 + (T_{\min} + 237.16)^4}{2}\ \left(0.34 - 0.14\sqrt{e_a}\right)\left(1.35\frac{R_s}{R_{so}} - 0.35\right)$$

where:
e_a = Step 2
R_s = Step 12
R_{so}= Step 11
σ = 4.903 x 10^{-9} $MJK^{-4}m^{-2}day^{-1}$

14. Calculate net solar radiation, R_{ns} [$MJm^{-2}\ day^{-1}$]

$$R_{ns} = (1 - \alpha)\ R_s$$

where:
R_s = Step 12
α = 0.23

15. Calculate net radiation, R_n [$MJm^{-2}\ day^{-1}$]

$$R_n = R_{ns} - R_{nl}$$

where:
R_{ns} = Step 14
R_{nl} = Step 13

16. Calculate slope vapour pressure, Δ [kPa °C^{-1}]

$$\Delta = \frac{2504\ \exp\left(\frac{17.27\,T}{T + 237.3}\right)}{\left(T + 237.3\right)^2}$$

17. Calculate atmospheric pressure, P [kPa]

$$P = 101.3 \left(\frac{293 - 0.0065\, z}{293} \right)^{5.26}$$

where:
z = elevation above sea level [m]

18. Calculate psychometric constant, γ [kPa °C^{-1}]

$$\gamma = 0.665 \times 10^{-3}\, P$$

where:
P = Step 17

19. Calculate evapotranspiration, ET_o

$$ET_o = \left[\frac{0.408\, \Delta\, R_n + \gamma \left(\frac{900}{T + 273} \right) u_2\, (e_s - e_a)}{\Delta + \gamma\ \ (1 + 0.34\, u_2)} \right]$$

APPENDIX D

Calculated Climatic Indices

All climate indices to be calculated on a calendar year basis for each Climate ID

Definitions
JD = Julian Day
GDD = growing degree day calculated from daily mean temperatures
FFD = frost free days
T_{max} = maximum daily temperature
T_{min} = minimum daily temperature
T_{mean} = mean daily temperature (T_{max} + T_{min})/2

1. Growing Season Length

Varies by crop

Growing season length = $JD_{start} – JD_{end}$

2. Beginning and End of the Growing Season

(The list of crops is incomplete. Provisions must be made for other crops to be added.)

Annual crops
(start and end (plant and harvest) can be temperature based or GDD accumulation based)
For a given Julian Day (JD_i):
Start growing season
For JD_i
if T_{mean} > base T for n consecutive days then $JD_i = JD_{start}$
End growing season (temperature base)
For JD_{start} + 50
if T_{mean} < base T or T_{min} = -2, whichever comes first, the $JD_i = JD_{end}$
End growing season (crop development base)
JD_{start} + hybrid season requirements

Design start index to identify start time for accumulation and end index to identify end time for critical temperatures or GDD accumulation (do not search for end index until 50 days after growing season starts)

CORN SILAGE
Start
base T Start: T_{mean} = 11.2; n = 3
(based on Vernon Coldstream Ranch 'normal' planting dates: May 1-7)
End
base T End: T_{mean} = 10.1
(based on Vernon Coldstream Ranch 'normal' occurrence Tmin = 0°C dates: Oct 3-10)

CORN SWEET
Start
base T Start: Tmean = 11.2; n = 3
(based on Vernon Coldstream Ranch 'normal' planting dates: May 1-7)
End
Jdend = Jdstart + 110

(based on FAO 56 Ch.6)

TOMATO; PEPPER

SPRING SEEDED CEREALS
Start
base T Start: $T_{mean} = 5$; $n = 5$
(based on FAO 56 Ch.6)
End
$JD_{end} = JD_{start} + 150$
(based on FAO 56 Ch.6)

Perennial crops (budbreak or bloomdate)
Start growing season
Based on start of GDD accumulation

APPLE (bloomdate)
JD_{start} = 0.7089 * (JDGDD10) + 49.04
Where JDGDD10 is Julian date of start of accumulation of GDD10 (see 4 below)
APRICOT, NECTARINE (bloomdate)
JD_{start} = 1.0168 * BloomDateApple – 22.028
CHERRY (bloomdate)
JD_{start} = 0.9832 * BloomDateApple – 7.9717
GRAPE (budbreak)
JD_{start} = 0.7089 * (JDGDD10) + 49.04
PEACH (bloomdate)
JD_{start} = 0.9028 * BloomDateApple + 2.5017
PEAR (bloomdate)
JD_{start} = 0.9419 * BloomDateApple + 3.21
PLUM (bloomdate)
JD_{start} = 0.9109 * BloomDateApple + 5.5583
PASTURE, GRASS FORAGE, ALFALFA (budbreak)
JD_{start} = JulianDayGDD5

End growing season
$JD_{end} = JD_{first\ killing\ frost}$ (see item 5 below)

3. Frost Free Days

Calculated cumulatively from the beginning of the calendar year

If $T_{min} > 0$ then
number of FFD = number of Frost Free Days + 1
Terminate calculation if Tmin < 0

4. Growing Degree Days

Use base $T(T_{mean}) = 5\ ^oC$ and $10\ ^oC$ with potential to add further base temperatures

Daily GDD = T_{mean} – base T (if T_{mean} < base T then GDD = 0)

Annual accumulation of growing degree days (calendar basis)

For a given Julian Day (JD_i)

If JD_i T_{mean} > base T then:

Cumulative GDD = cumulative GDD + (JD_i T_{mean} – 5)

Starts after five consecutive days with T_{mean} > base T
Ends after five consecutive days with T_{mean} < base T
Design start index to identify start time for accumulation and end index to identify end time for GDD accumulation (do not search for end index until 50 days after GDD accumulation starts)

5. First, Last and Killing Frost

On an annual basis, determine date of last frost in spring, first frost and first killing frost in fall.

If JD > 0 and if JD < 181 then:
date of last frost = max value JD where $T_{min} \leq 0$
If JD > 181 and if JD < 366 then:
date of first frost = min value JD where $T_{min} \leq 0$
If JD > 181 and if JD < 366 then:
date of killing frost = min value JD where $T_{min} \leq -2$

6. Corn Heat Units

Average daily values of CHU were computed after Brown and Bootsma (1993), using the following formula:

$$CHU = \frac{\left[3.33\,(T_{\max} - 10.0) - 0.084\,(T_{\max} - 10.0)^2 + 1.8\,(T_{\min} - 4.44)\right]}{2}$$

7. Effective Precipitation

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

where Precip = Precipitation ≥ 5 mm

Calculated Crop Indices

1. Availability Coefficient

$AC = AC_t + 0.04\,(5 - ET_o)$

2. Crop Coefficients
based on days since JD_{start}
keep number of decimal places

ANNUAL CROPS

CORN SILAGE 150 DAY HYBRID

$K_c = -0.00000173^* (JD-JD_{start})^3 + 0.00028969^*(JD-JD_{start})^2 - 0.00217336(JD-JD_{start}) + 0.22549316$

CORN SILAGE 170 DAY HYBRID

$K_c = -0.0000008183*(JD-JD_{start})^3 + 0.0001304380*(JD-JD_{start})^2 + 0.0043141319*(JD-JD_{start}) + 0.1895878926$

BELL PEPPERS

$K_c = 0.0000000164*(JD-JD_{start})^4 - 0.0000053572*(JD-JD_{start})^3 + 0.0004767069*(JD-JD_{start})^2 - 0.0045795940*(JD-JD_{start}) + 0.5413533229$

CEREALS (SPRING-SEEDED)

$K_c = -0.0000039449*(JD-JD_{start})^3 + 0.0005969228*(JD-JD_{start})^2 - 0.0106888006*(JD-JD_{start}) + 0.2280576592$

CUCURBITS

$K_c = 0.0000000294*(JD-JD_{start})^4 - 0.0000082782*(JD-JD_{start})^3 + 0.0006143669*(JD-JD_{start})^2 - 0.0039347922*(JD-JD_{start}) + 0.4359403315$

POTATO – LONG SEASON WITH VINE KILL

$K_c = -0.0000013745*(JD-JD_{start})^3 + 0.0002449713*(JD-JD_{start})^2 - 0.0028533427*(JD-JD_{start}) + 0.3968596247$

PUMPKIN

$K_c = 0.0000000246*(JD-JD_{start})^4 - 0.0000071579*(JD-JD_{start})^3 + 0.0005705239*(JD-JD_{start})^2 - 0.0045023884*(JD-JD_{start}) + 0.3996233199$

TOMATO, EGGPLANT

$K_c = 0.0000000131*(JD-JD_{start})^4 - 0.0000049681*(JD-JD_{start})^3 + 0.0005019133*(JD-JD_{start})^2 - 0.0067404919*(JD-JD_{start}) + 0.4937937496$

PERENNIAL CROPS

ALFALFA

First cut

$K_c = 0.00000015*(JD-JD_{start})^4 - 0.00003200*(JD-JD_{start})^3 + 0.00180915*(JD-JD_{start})^2 - 0.01146027*(JD-JD_{start}) + 0.39061416$

Second and subsequent cut

$K_c = -0.00002500*(JD-JD_{start})^3 + 0.00021429*(JD-JD_{start})^2 + 0.04392857*(JD-JD_{start}) + 0.39285714$

Final cut/pasture

$K_c = 0.00001042*(JD-JD_{start})^3 - 0.00162500*(JD-JD_{start})^2 + 0.06833333*(JD-JD_{start}) + 0.40000000$

PASTURE/FORAGE

$K_c = 0.00000007*(JD-JD_{start})^3 - 0.00003037*(JD-JD_{start})^2 + 0.00364019*(JD-JD_{start}) + 0.91760724$

APPLE, CHERRY, SOURCHERRY, NUTS

$K_c = 0.0000000011*(JD-JD_{start})^4 - 0.0000006128*(JD-JD_{start})^3 + 0.0000789103*(JD-JD_{start})^2 + 0.0034721982*(JD-JD_{start}) + 0.4338842227$

APRICOT, NECATRINE,PEACH, PLUM, NUTS

$K_c = 0.0000000005*(JD-JD_{start})^4 - 0.0000003509*(JD-JD_{start})^3 + 0.0000464923*(JD-JD_{start})^2 + 0.0038321474*(JD-JD_{start}) + 0.4433701126$

GRAPE

$K_c = 0.0000000031 * (JD-JD_{start})^4 – 0.0000013775 * (JD-JD_{start})^3 + 0.0001634536 * (JD-JD_{start})^2 – 0.0011179845 * (JD-JD_{start}) + 0.2399004137$

BLUEBERRY, RASPBERRY

$K_c = 0.0000000053 * (JD-JD_{start})^4 – 0.0000024204 * (JD-JD_{start})^3 + 0.0002930277 * (JD-JD_{start})^2 – 0.0025162017 * (JD-JD_{start}) + 0.2434784686$

APPENDIX E

Crop Information

The following crop codes have been used and stored in the land use database. A crop coefficient has been determined for each crop for various stages of growth. Land use was collected using the column labelled Current Code. For the purpose of the Agriculture Water Demand Model, some codes have been amalgamated and the codes under Model Code will be used. The rooting depths to be used for each crop in the model are also shown.

Land Use Coding				
Current Code	**CropID**	**Rooting Depth [m]**	**Availability Coefficient**	**Drip Factor**
Abandoned or neglected farm land Inactive agricultural land and facilities Land in transition Land in transition, changing agricultural use Range	Inactive			
Tree fruit crops Apples	AppleMD	0.9	0.4	0.8
	AppleHD AppleLD	0.6 1.2	0.4 0.4	1.0 0.7
Apricots Asparagus	Apricot Asparagus	0.9 1.2	0.4 0.45	0.8 1.0
Berries Vine and berry crops Other/unknown berries	Berry	0.9	0.5	0.7
Blueberries	Blueberry	0.6	0.5	0.8
Cherries	CherryHD CherryMD CherryLD	0.6 0.9 1.2	0.4 0.4 0.4	1.0 0.8 0.7
Sour cherries	Sourcherry	0.9	0.4	0.8
Commercial greenhouse (glass) Commercial greenhouse (polyhouse)				

Land Use Coding				
Current Code	**CropID**	**Rooting Depth [m]**	**Availability Coefficient**	**Drip Factor**
Commercial greenhouse – floriculture Commercial greenhouse – nursery Commercial greenhouse – vegetables Polyhouse – heated	Greenhouse			
Cultivated land Forage and pasture crops Forage cereal	Forage	0.9	0.55	1.0
Legume (forage and pasture)	Alfalfa	1.2	0.55	1.0
Forage corn	Corn	1.2	0.55	1.0
Sweet corn	Sweetcorn	0.9	0.55	1.0
Grains, cereals and oilseeds Wheat Oats Rye Barley	Cereal	0.9	0.55	1.0
Ginseng	Ginseng	0.45	0.5	0.8
Grapes	Grape	1.2	0.4	0.7
Hazelnut Nuts Walnut	Nuts	1.2	0.5	0.8
Nursery/trees Ornamentals and shrubs Other/unknown trees Shrubs Misc. specialty plants Specialty plants Christmas trees Floriculture	Nursery	0.9	0.5	0.8
Nectarines	Nectarine	0.9	0.4	0.8
Peaches	Peach	0.9	0.4	0.8
Pears	Pear	1.2	0.4	0.8
Plums	Plum	0.9	0.4	0.8
Potatoes	Potatoe	0.6	0.35	0.75
Raspberries	Raspberry	1.2	0.5	0.7

Land Use Coding				
Current Code	**CropID**	**Rooting Depth [m]**	**Availability Coefficient**	**Drip Factor**
Strawberries	Strawberry	0.6	0.5	0.75
Tomatoes	Tomatoe	0.6	0.4	0.9
Grass Pasture and Forage	Grass	0.45	0.5	1.0
Turf	Turf	0.2	0.5	1.0
Peppers	Pepper	0.5	0.3	0.75
Pumpkins	Pumpkin	0.5	0.35	0.75
Cucurbits Echinacea Lavender Misc. vegetables Vegetables Field crop production Unspecified/other crops Herbs	Vegetable	0.45	0.5	0.75

APPENDIX F

Irrigation Information

The following irrigation have been used and stored in the land use database. Irrigation system information was collected using the column labelled Current Code. For the purpose of the Agriculture Water Demand Model, the codes under IrrigID will be used. The irrigation system efficiency that is to be used by the model is indicated for each irrigation system type.

Current Code	IrrigID	Irrigation Efficiency [%]
Centre pivot sprinkler irrigation	Pivot	72
Centre pivot sprinkler irrigation, low pressure pivot	PivotLP	80
Sprinkler irrigation		
Surface irrigation	Sprinkler	72
Irrigation		
Tripod sprinkler		
Handline irrigation	Handline	70
Wheeline sprinkler irrigation	Wheeline	72
Solid set irrigation	Sssprinkler	72
Solid set irrigation, overtree	Ssovertree	70
Solid set irrigation, undertree	Ssundertree	74
Microsprinkler irrigation	Microsprinkler	78
Overtree and drip	Overtreedrip	92
Overtree and microsprinkler	Overtreemicro	78
Giant gun irrigation	Gun	60
Giant gun irrigation, stationary gun		
Giant gun irrigation, solid set gun	Ssgun	62
Giant gun irrigation, travelling gun	Travgun	65
Trickle irrigation		
Trickle irrigation, drip emitter	Drip	92
Trickle irrigation, drip emitter, aboveground		
Trickle irrigation, drip emitter, buried	SDI	95
Trickle irrigation, spray emitter	Microspray	88
Flood	Flood	40
Sub-surface irrigation	Subirrig	90
No irrigation	Irrignotused	

APPENDIX G

Soil Information

The soil type coverage for the Okanagan Basin that is stored in the model is shown in the table below. For the purpose of the Agriculture Water Demand Model, the Available Water Storage Capacity (AWSC) that is assigned to each soil type is shown.

Soil Type	
Model Code	**AWSC [mm of water per m of soil]**
Clay	200
Loam	175
Loamy Sand	100
Sand	85
Silt Clay Loam	200
Silt Loam	210
Sandy Loam	125

The following table provides the parameters that are used in the algorithm that calculates the Irrigation Requirement (IR).

Algorithm Parameter	*Maximum Soil Water Deficit (mm)*					
	12	25	50	75	100	*125*
a_0	253.39	222.73	176.48	150.80	127.74	*102.05*
a_1	0.2167	0.2478	0.3005	0.2676	0.2643	*0.2461*
a_2	*0.0011*	*0.0011*	*0.0011*	*0.0012*	*0.0012*	*0.0012*

APPENDIX H

Sub-basins (organized roughly from north to south)

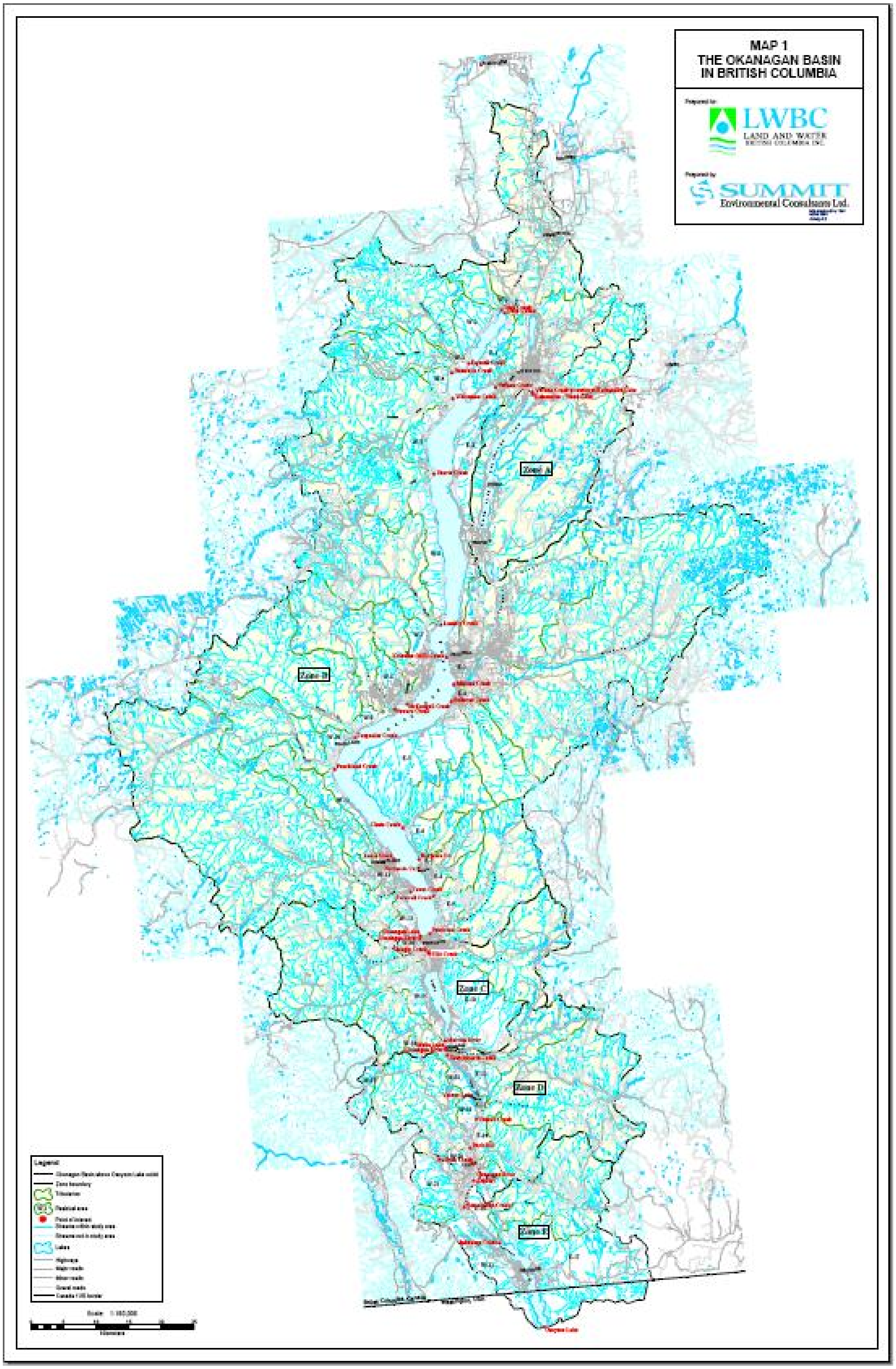
ZONE[1]	No.	POINTS-OF-INTEREST	
		West side of Okanagan Basin	***East side of Okanagan Basin***
A	1		**Vernon Creek at outlet of Kalamalka Lake**
	2		**Kalamalka – Wood Lake**
B	3	**Deep Creek (mouth)**	
	4	Residual area W-1	
	5	**Irish Creek (mouth)**	
	6	Residual area W-2	
	7		Residual area E-1
	8	**Equesis Creek (mouth)**	
	9	Residual area W-3	
	10	**Nashwhito Creek (mouth)**	
	11	Residual area W-4	
	12		**Vernon Creek (mouth); includes Zone A & B**
	13		Residual area E-2
	14	**Whiteman Creek (mouth)**	
	15	Residual area W-5	
	16	**Shorts Creek (mouth)**	
	17	Residual area W-6	
	18	**Lambly Creek (mouth)**	
	19	Residual area W-7	
	20		**Kelowna (Mill) Creek (mouth)**
	21		Residual area E-3
	22		**Mission Creek (mouth)**
	23		Residual area E-4
	24		**Bellevue Creek (mouth)**
	25		Residual area E-5
	26	**McDougall Creek (mouth)**	
	27	Residual area W-8	
	28	**Powers Creek (mouth)**	
	29	Residual area W-9	
	30	**Trepanier Creek (mouth)**	
	31	Residual area W-10	
	32	**Peachland Creek (mouth)**	
	33	Residual area W-11	
	34		**Chute Creek (mouth)**
	35		Residual area E-6
	36	**Eneas Creek (mouth)**	
	37	Residual area W-12	
	38		**Robinson Creek (mouth)**
	39		Residual area E-7
	40		**Naramata Creek (mouth)**
	41		Residual area E-8
	42	**Trout Creek (mouth)**	
	43	Residual area W-13	
	44		**Turnbull Creek**
	45		Residual area E-9
	46		**Penticton Creek (mouth)**
	47	**Okanagan Lake**	
	48	**Okanagan River at Penticton**	

Sub-basins continued:

ZONE[1]	No.	POINTS-OF-INTEREST	
		West side of Okanagan Basin	***East side of Okanagan Basin***
C	49	Residual area W-14	
	50		Residual area E-10
	51	**Shingle Creek (mouth)**	
	52		**Ellis Creek (mouth)**
	53	Residual area W-15	
	54		Residual area E-11
	55	**Marron River**	
	56	Residual area W-16	
	57	**Skaha Lake**	
	58	**Okanagan River at Okanagan Falls**	
D	59		**Shuttleworth Creek (mouth)**
	60	Residual area W-18	
	61		Residual area E-12
	62	**Vaseux Lake**	
	63		Residual area E-13
	64		**Vaseux Creek (mouth)**
	65	Residual area W-19	
	66		Residual Area E-14
	67	**Park Rill (mouth)**	
	68	Residual area W-20	
	69		**Wolfcub Creek (mouth)**
	70		Residual area E-15
	71	**Okanagan River near Oliver**	
E	72	Residual area W-21	
	73		Residual area E-16
	74	**Testalinden Creek (mouth)**	
	75	Residual area W-22	
	76		**Inkaneep Creek (mouth)**
	77		Residual area E-17
	78	**Osoyoos Lake**	
A,B,C,D,E	79	**Okanagan Basin within British Columbia**	

Notes: 1. Refer to Map 1 for zone boundaries and locations of sub-basins.

A **map showing the location of the sub-basins is shown in the figure below.**


MAP 1
THE OKANAGAN BASIN
IN BRITISH COLUMBIA
LWBC
LAND AND WATER
SUMMIT
Environmental Consultants Ltd.
Zone A
Zone B
Zone C
Zone D
Zone E
Legend

APPENDIX I

Example Water Use Report

South East Kelowna Irrigation District

Irrigation Monitoring Program
Water Use Report

MR OWNER
200 MY ROAD
THISTOWN BC
VVV 123 CANADA

21 May, 1999

Water use report for the period: 03-Sep-98 to 30-Sep-98

The South East Kelowna Irrigation District is monitoring water use on all irrigated lands in the district. This water use report is intended as a guide to assist you in evaluating your irrigation practices. The report provides you with three key pieces of information in both standard and metric units:

1. Your **Water Use** for both the month and the year to date, expressed as a volume of water and as the comparable depth of water this amount represents over the irrigated acreage of your property.
2. The district's **Calculated Water Requirement** for the period and year to date. This estimate is based on your crop type(s), irrigation system(s), soil, and weather.
3. The **Average Water Use** for both the period and year to date of other irrigation users similar crops, soil and irrigation systems.

   Our records show the following information for your property. If this information needs to be updated, please contact the district office (861-4200).

Property Owner: MR OWNER
Property Address: 200 MY ROAD
Legal Description: **Plan:** 187 **Lot:** A

Irrigated Acreage: 5.5
Grade 'A' Acreage: 6

Primary Land Use: apple low density
Primary Irrigation System: hand move

Primary Soil Type: sandy loam

Evaporation for the month: **inch:** 4 **mm:** 95

Water Use

	Your Water Use (volume)		Your Water Use (depth)		Calculated Water Requirement	
	US gallons	cubic meters	inches	mm	inches	mm
Current Month	741100	2805.06	4.96	126	4.85	123
Year to Date	6133500	23215.3	41.07	1043	32.33	821

Average Water Use for:

apple low density

	Average Use for Properties with Similar Soil and Crop Type		Amount Over or Under the Average		
	inches	mm	inches	mm	%
Current Month	3.12	79	1.84	47	60
Year to Date	32.73	831	8.34	212	25

Appendix G - Complete Factors Table Listings

This appendix provides the full set of values for the factors tables in an unmodified distribution version of the application (currently version 2009.04.29). See Appendix B for descriptions of the table structures.

Growing Season Overrides table (growing_season_overrides)

Note: the use of the growing season overrides table is described in the Irrigation Water Demand – User's Guide.

cropid	Minimum Start day	Maximum Start day	Minimum Season length	Maximum Season length	Minimum End day	**Maximum End day**
Alfalfa						275
AppleHD						275
AppleLD						275
AppleMD						275
Apricot						275
Asparagus						250
Berry						275
Blank	1	0	0	0	0	366
Blueberry						275
Cereal						250
CherryHD						275
CherryLD						275
CherryMD						275
Corn						250
Domestic						275
Forage						275
Ginseng						275
Golf						275
Grape						250
Grass						275
Greenhouse						275
Nectarine						275
Nursery						275
Nuts						275
Peach						275
Pear						275
Plum						275
Potato						240
Pumpkin						275
Raspberry						275
Sourcherry						275
Strawberry						240
Sweetcorn						240
Tomato						250
TurfFarm						275
TurfPark						275
Vegetable						240
Yard						275

Alfalfa Cuttings table (alfalfa_cuttings)

growing season length	first cut days	second cut days	third cut days	fourth cut days	rationale
120	55	55	0	0	can't get 3rd cut without 35 days for each after first; stay with 55 days for 2nd cut
121	55	55	0	0	
122	55	55	0	0	
123	55	55	0	0	
124	55	55	0	0	
125	55	35	35	0	1st chance to get 3 cuts with 35 days for 2nd
126	55	36	35	0	bring second cut back to 40
127	55	37	35	0	
128	55	38	35	0	
129	55	39	35	0	
130	55	40	35	0	
131	55	40	36	0	bring third cut to 40
132	55	40	37	0	
133	55	40	38	0	

134	55	40	39	0	
135	55	40	40	0	
136	55	41	40	0	can't get 4th cut until at least 30 days for it; return 2nd cut to 55
137	55	42	40	0	
138	55	43	40	0	
139	55	44	40	0	
140	55	45	40	0	
141	55	46	40	0	
142	55	47	40	0	
143	55	48	40	0	
144	55	49	40	0	
145	55	50	40	0	
146	55	51	40	0	
147	55	52	40	0	
148	55	53	40	0	
149	55	54	40	0	
150	55	55	40	0	
151	55	55	41	0	retain 2nd cut at 55, lengthen 3rd
152	55	55	42	0	
153	55	55	43	0	
154	55	55	44	0	
155	55	35	35	30	1st chance to get 4th cut with 30 days without dropping intermediates below 35
156	55	36	35	30	bring 2nd cut back to 40
157	55	37	35	30	
158	55	38	35	30	
159	55	39	35	30	
160	55	40	35	30	
161	55	40	36	30	bring 3rd cut back to 40
162	55	40	37	30	
163	55	40	38	30	
164	55	40	39	30	
165	55	40	40	30	
166	55	40	40	31	bring 4th cut to 40
167	55	40	40	32	
168	55	40	40	33	
169	55	40	40	34	
170	55	40	40	35	
171	55	40	40	36	
172	55	40	40	37	
173	55	40	40	38	
174	55	40	40	39	
175	55	40	40	40	
176	55	41	40	40	increase growing season by increasing 2nd and 3rd cuts up to 55
177	55	42	40	40	
178	55	43	40	40	
179	55	44	40	40	
180	55	45	40	40	
181	55	46	40	40	
182	55	47	40	40	
183	55	48	40	40	
184	55	49	40	40	
185	55	50	40	40	
186	55	51	40	40	
187	55	52	40	40	
188	55	53	40	40	
189	55	54	40	40	
190	55	55	40	40	
191	55	55	41	40	
192	55	55	42	40	
193	55	55	43	40	
194	55	55	44	40	
195	55	55	45	40	
196	55	55	46	40	
197	55	55	47	40	
198	55	55	48	40	
199	55	55	49	40	
200	55	55	50	40	

Crop Factors and Coefficients table (crop_factors)

cropId	crop Group	rooting Depth	avail. Coeff.	drip Factor	stress Factor	coefficient_4	coefficient_3	coefficient_2	coefficient_1	coefficient_0
Alfalfa	Alfalfa	1.2	0.55	1	1	0.00000009	-0.00001968	0.00116367	-0.00702017	0.39164308
AlfalfaFirst	Alfalfa	1.2	0.55	1	1	0.00000009	-0.00001968	0.00116367	-0.00702017	0.39164308
AlfalfaIntermediate	Alfalfa	1.2	0.55	1	1	0	0.00000833	-0.00125	0.05166667	0.4
AlfalfaLast	Alfalfa	1.2	0.55	1	1	0	0.00000833	-0.00125	0.05166667	0.4
AppleHD	Apple	0.6	0.4	1	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
AppleLD	Apple	1.2	0.4	0.7	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
AppleMD	Apple	0.9	0.4	0.8	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
Apricot	Fruit	0.9	0.4	0.8	1	0.0000000005	-0.0000003696	0.0000487044	0.0038506624	0.3550454057
Asparagus	Vegetable	1.2	0.45	1	1	0.0000000006	-0.0000004067	0.0000607108	0.0013034454	0.4710628744
Berry	Berry	0.9	0.5	0.7	1	0.0000000051	-0.0000023417	0.0002781616	-0.0019823704	0.2432532741
Blank	Inactive	0.2	0.5	1	1	0	0	0	0	0
Blueberry	Berry	0.6	0.5	0.8	1	0.0000000051	-0.0000023417	0.0002781616	-0.0019823704	0.2432532741
Cereal	Forage	0.9	0.55	1	1	0	-0.0000031178	0.0004615398	-0.00669897	0.2141133633
CherryHD	Cherry	0.6	0.4	1	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
CherryLD	Cherry	1.2	0.4	0.7	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
CherryMD	Cherry	0.9	0.4	0.8	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
Corn	Corn	1.2	0.55	1	1	0	-0.00000086	0.00015707	0.00018757	0.23169089
Corn150	Corn	1.2	0.55	1	1	0	-0.00000124	0.00019435	0.00152482	0.17842738
Domestic	Domestic	0.2	0.5	1	0.7	0	0	0	0	1
Forage	Forage	0.9	0.55	1	1	0	0.00000007	-0.00003037	0.00364019	0.91760724
Ginseng	Vegetable	0.45	0.5	0.8	1	0.0000000031	-0.0000013775	0.0001634536	-0.0011179845	0.2399004137
Golf	Golf	0.2	0.5	1	0.75	0	0	0	0	1
Grape	Grape	1.2	0.4	0.7	1	0.0000000031	-0.0000013775	0.0001634536	-0.0011179845	0.2399004137
Grass	Forage	0.45	0.5	1	0.75	0	0	0	0	1
Greenhouse	Nursery	0.2	0.5	1	1	0	0	0	0	1
Inactive	Inactive	0.2	0.5	1	1	0	0	0	0	0
Nectarine	Fruit	0.9	0.4	0.8	1	0.0000000005	-0.0000003696	0.0000487044	0.0038506624	0.3550454057
Nursery	Nursery	0.9	0.5	0.8	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
Nuts	Fruit	1.2	0.5	0.8	1	0.0000000005	-0.0000003696	0.0000487044	0.0038506624	0.3550454057
Peach	Fruit	0.9	0.4	0.8	1	0.0000000005	-0.0000003696	0.0000487044	0.0038506624	0.3550454057
Pear	Fruit	1.2	0.4	0.8	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
Pepper	Vegetable	0.5	0.3	0.75	1	0.0000000164	-0.0000053572	0.0004767069	-0.004579594	0.5413533229
Plum	Fruit	0.9	0.4	0.8	1	0.0000000005	-0.0000003696	0.0000487044	0.0038506624	0.3550454057
Potato	Vegetable	0.6	0.35	0.75	1	0	-0.0000013745	0.0002449713	-0.0028533427	0.3968596247
Pumpkin	Vegetable	0.5	0.35	0.75	1	0.0000000246	-0.0000071579	0.0005705239	-0.0045023884	0.3996233199
Raspberry	Berry	1.2	0.5	0.7	1	0.0000000051	-0.0000023417	0.0002781616	-0.0019823704	0.2432532741
Sourcherry	Cherry	0.9	0.4	0.8	1	0.0000000011	-0.0000005957	0.0000735096	0.0030611779	0.3499385399
Strawberry	Berry	0.6	0.5	0.75	1	0.000000011	-0.000004549	0.0004722314	-0.0039611341	0.203054929
Sweetcorn	Vegetable	0.9	0.55	1	1	-0.0000000153	-0.0000005932	0.0002543513	-0.0015212354	0.4024757053
Tomato	Vegetable	0.6	0.4	0.9	1	0.0000000131	-0.0000049681	0.0005019133	-0.0067404919	0.4937937496
TurfFarm	Turf Farm	0.2	0.5	1	0.75	0	0	0	0	1
TurfPark	Landscape Turf	0.2	0.5	1	0.7	0	0	0	0	1
Vegetable	Vegetable	0.45	0.5	0.75	1	0.0000000294	-0.0000082782	0.0006143669	-0.0039347922	0.4359403315
Yard	Landscape Turf	0.2	0.5	1	0.7	0	0	0	0	1

Greenhouse Factors table (greenhouse_factors)

monthNumber	greenhouseFactor
1	0
2	1.2
3	1.5
4	1.5
5	1.6
6	1.8
7	1.8
8	1.3
9	1.3
10	1.3
11	0
12	0

Irrigation Efficiencies table (irrigation_factors)

irrigid	irrigationEfficiency	comments
Blank	0.72	Unknown system - use Sprinkler parameters
Drip	0.92	
Flood	0.4	
Golfsprinkler	0.72	
Gun	0.55	
Handline	0.7	
Landscapedrip	0.95	
Landscapespray	0.75	
Landscapesprinkler	0.7	
Microspray	0.88	
Microsprinkler	0.82	
Overtreedrip	0.92	
Overtreemicro	0.78	
Pivot	0.72	
PivotLP	0.8	
SDI	0.95	
Sprinkler	0.72	
Ssgun	0.62	
Ssovertree	0.7	
Sssprinkler	0.72	
Ssundertree	0.74	
Subirrig	0.9	
Travgun	0.65	
Wheelline	0.72	

Soil Factors table (soil_factors)

soilid	soilClass	availableWaterStorageCapacity_mm	maximumEvaporation
C	Clay	200	29
default	Sandy Loam (defaulted)	125	20
FSL	Fine Sandy Loam	142	21
HC	Heavy Clay	208	30
L	Loam	167	22
LS	Loamy Sand	100	14
O	Organic	250	36
S	Sand	83	12
SCL	Sandy Clay Loam	167	23
SI	Silt	167	23
SIC	Silty Clay	208	28
SICL	Silty Clay Loam	200	27
SIL	Silt Loam	192	25
SL	Sandy Loam	125	20
VCSL	Very Coarse Sandy Loam	83	12
VFSL	Very Fine Sandy Loam	167	23

Soil Water Factors table (soil_water_factors)

maximumSoilWaterDeficit	soilWaterFactor
25	1.05
50	1
75	0.85
100	0.75
125	0.65

Soil Percolation factors table (soil_percolation_factors)

SoilId	Soil Class	MSWD	Infiltration Rate (mm)	Gun - poor	Gun - good	Gun - avg	SsGun - poor	SsGun - good	SsGun - avg	Travgun - poor	Travgun - good	Travgun - avg	Handline - poor	Handline - good	Handline - avg	Sprinkler - poor	Sprinkler - good	Sprinkler - avg
C	clay	50	0.1	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
C		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
C		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
C		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CL	clay loam	50	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
CL		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
CL		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CL		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CS	clayey sand	25	0.35	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
CS		38		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
CS		50		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CS		75		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CSL	clayey sandy loam	25	0.25	0.3	0.2	0.25	0.3	0.2	0.25	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
CSL		38		0.25	0.2	0.225	0.25	0.2	0.225	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
CSL		50		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
CSL		75		0.2	0.15	0.175	0.2	0.15	0.175	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
default	default	25	0.25	0.35	0.35	0.35	0.35	0.35	0.35	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
default		38		0.3	0.25	0.275	0.3	0.25	0.275	0.25	0.1	0.175	0.25	0.1	0.175	0.25	0.1	0.175
default		50		0.25	0.2	0.225	0.25	0.2	0.225	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
default		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
FSL	fine sandy loam	38	0.25	0.3	0.25	0.275	0.3	0.25	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
FSL		50		0.25	0.2	0.225	0.25	0.2	0.225	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
FSL		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
FSL		100		0.2	0.15	0.175	0.2	0.15	0.175	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HC	heavy clay	50	0.1	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
HC		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
HC		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
HC		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
L	loam	38	0.2	0.3	0.15	0.225	0.3	0.15	0.225	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
L		50		0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
L		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
L		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
LCS	loamy clayey sand	25	0.35	0.45	0.35	0.4	0.45	0.35	0.4	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
LCS		38		0.4	0.3	0.35	0.4	0.3	0.35	0.25	0.15	0.2	0.25	0.15	0.2	0.2	0.15	0.175
LCS		50		0.35	0.2	0.275	0.35	0.2	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.15	0.15
LCS		75		0.3	0.2	0.25	0.3	0.2	0.25	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
LFS	loamy fine sand	25	0.35	0.45	0.35	0.4	0.45	0.35	0.4	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
LFS		38		0.4	0.3	0.35	0.4	0.3	0.35	0.25	0.15	0.2	0.25	0.15	0.2	0.2	0.15	0.175
LFS		50		0.35	0.2	0.275	0.35	0.2	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.15	0.15
LFS		75		0.3	0.2	0.25	0.3	0.2	0.25	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
LS	loamy sand	25	0.35	0.45	0.35	0.4	0.45	0.35	0.4	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
LS		38		0.4	0.3	0.35	0.4	0.3	0.35	0.25	0.15	0.2	0.25	0.15	0.2	0.2	0.15	0.175
LS		50		0.35	0.2	0.275	0.35	0.2	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.15	0.15
LS		75		0.3	0.2	0.25	0.3	0.2	0.25	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
O	organic	50	0.5	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
O		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
O		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
O		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
S	sand	25	0.4	0.5	0.35	0.425	0.5	0.35	0.425	0.35	0.25	0.3	0.35	0.25	0.3	0.3	0.25	0.275
S		38		0.45	0.3	0.375	0.4	0.3	0.35	0.3	0.15	0.225	0.3	0.15	0.225	0.25	0.15	0.2
S		50		0.4	0.2	0.3	0.35	0.2	0.275	0.25	0.15	0.2	0.25	0.15	0.2	0.2	0.15	0.175
SCL	sandy clay loam	38	0.15	0.3	0.2	0.25	0.3	0.2	0.25	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
SCL		50		0.25	0.2	0.225	0.25	0.2	0.225	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SCL		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SCL		100		0.2	0.15	0.175	0.2	0.15	0.175	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SI	silt	38	0.2	0.3	0.25	0.275	0.3	0.25	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
SI		50		0.25	0.2	0.225	0.25	0.2	0.225	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SI		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SI		100		0.2	0.15	0.175	0.2	0.15	0.175	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC	silty clay	50	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SIC		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SIC		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SICL	silty clay loam	50	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SICL		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SICL		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SICL		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIL	silt loam	50	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125

SIL		75		0.2	0.1	0.15	0.2	0.1	0.15	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SIL		100		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIL		125		0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SL	sandy loam	25	0.25	0.35	0.35	0.35	0.35	0.35	0.35	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
SL		38		0.3	0.25	0.275	0.3	0.25	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
SL		50		0.25	0.2	0.225	0.25	0.2	0.225	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SL		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
VCSL	very coarse sandy loam	25	0.25	0.5	0.35	0.425	0.5	0.35	0.425	0.35	0.25	0.3	0.35	0.25	0.3	0.3	0.25	0.275
VCSL		38		0.4	0.3	0.35	0.4	0.3	0.35	0.3	0.15	0.225	0.3	0.2	0.25	0.25	0.2	0.225
VCSL		50		0.35	0.2	0.275	0.35	0.2	0.275	0.25	0.15	0.2	0.25	0.15	0.2	0.2	0.15	0.175
VFSL	very fine sandy loam	38	0.25	0.3	0.25	0.275	0.3	0.25	0.275	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
VFSL		50		0.25	0.2	0.225	0.25	0.2	0.225	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
VFSL		75		0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
VFSL		100		0.2	0.15	0.175	0.2	0.15	0.175	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

SoilId	Soil Class	MSWD	Infiltration Rate (mm)	Wheelline - poor	Wheelline - good	Wheelline - avg	Ssovertre e - poor	Ssovertre e - good	Ssovertre e - avg	Sssprinkl er - poor	Sssprinkl er - good	Sssprinkl er - avg	Ssundertr ee - poor	Ssundertr ee - good	Ssundertr ee - avg	Pivot - poor	Pivot - good	Pivot - avg
C	clay	50	0.1	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
C		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
C		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
C		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
CL	clay loam	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
CL		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
CL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
CL		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
CS	clayey sand	25	0.35	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
CS		38		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
CS		50		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
CS		75		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
CSL	clayey sandy loam	25	0.25	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
CSL		38		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
CSL		50		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
CSL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
default	default	25	0.25	0.3	0.25	0.275	0.3	0.2	0.25	0.3	0.2	0.25	0.3	0.2	0.25	0.1	0.1	0.1
default		38		0.25	0.1	0.175	0.25	0.1	0.175	0.25	0.1	0.175	0.25	0.1	0.175	0.1	0.1	0.1
default		50		0.2	0.1	0.15	0.2	0.05	0.125	0.2	0.05	0.125	0.2	0.05	0.125	0.1	0.1	0.1
default		75		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
FSL	fine sandy loam	38	0.25	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
FSL		50		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
FSL		75		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
FSL		100		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
HC	heavy clay	50	0.1	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
HC		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
HC		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
HC		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
L	loam	38	0.2	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
L		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
L		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
L		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
LCS	loamy clayey sand	25	0.35	0.3	0.25	0.275	0.3	0.2	0.25	0.3	0.2	0.25	0.3	0.2	0.25	0.15	0.1	0.125
LCS		38		0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125
LCS		50		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
LCS		75		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
LFS	loamy fine sand	25	0.35	0.3	0.25	0.275	0.3	0.2	0.25	0.3	0.2	0.25	0.3	0.2	0.25	0.15	0.1	0.125
LFS		38		0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125
LFS		50		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
LFS		75		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
LS	loamy sand	25	0.35	0.3	0.25	0.275	0.3	0.2	0.25	0.3	0.2	0.25	0.3	0.2	0.25	0.15	0.1	0.125
LS		38		0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.15	0.1	0.125
LS		50		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
LS		75		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
O	organic	50	0.5	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
O		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
O		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
O		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
S	sand	25	0.4	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275	0.15	0.1	0.125
S		38		0.25	0.15	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125
S		50		0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
SCL	sandy clay loam	38	0.15	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
SCL		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SCL		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SCL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SI	silt	38	0.2	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
SI		50		0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
SI		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SI		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SIC	silty clay	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SIC		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SIC		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SIC		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SICL	silty clay loam	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SICL		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SICL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SICL		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SIL	silt loam	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1

SIL		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SIL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SIL		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05
SL	sandy loam	25	0.25	0.25	0.25	0.25	0.25	0.2	0.225	0.25	0.2	0.225	0.25	0.2	0.225	0.1	0.1	0.1
SL		38		0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
SL		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
SL		75		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
VCSL	very coarse sandy loam	25	0.25	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275	0.15	0.1	0.125
VCSL		38		0.25	0.2	0.225	0.25	0.15	0.2	0.25	0.15	0.2	0.25	0.15	0.2	0.15	0.1	0.125
VCSL		50		0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
VFSL	very fine sandy loam	38	0.25	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.1	0.1	0.1
VFSL		50		0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
VFSL		75		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.1	0.1
VFSL		100		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.05	0.05	0.05

SoilId	Soil Class	MSWD	Infiltration Rate (mm)	PivotLP - poor	PivotLP - good	PivotLP - avg	Microsprinkler - poor	Microsprinkler - good	Microsprinkler - avg	Overtree micro - poor	Overtree micro - good	Overtree micro - avg	Microspray - poor	Microspray - good	Microspray - avg	Overtree drip - poor	Overtree drip - good	Overtree drip - avg
C	clay	50	0.1	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
C		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
C		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
C		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
CL	clay loam	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
CL		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CL		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
CS	clayey sand	25	0.35	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
CS		38		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CS		50		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CS		75		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
CSL	clayey sandy loam	25	0.25	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.15	0.1	0.125
CSL		38		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
CSL		50		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CSL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
default	default	25	0.25	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
default		38		0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
default		50		0.1	0.1	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.1	0.1	0.1
default		75		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
FSL	fine sandy loam	38	0.25	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
FSL		50		0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.1	0.1	0.1
FSL		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.1	0.1	0.1	0.1	0.1
FSL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
HC	heavy clay	50	0.1	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
HC		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
HC		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
HC		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
L	loam	38	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
L		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
L		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
L		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
LCS	loamy clayey sand	25	0.35	0.25	0.1	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
LCS		38		0.2	0.1	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
LCS		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.1	0.1	0.1
LCS		75		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.1	0.1	0.1	0.1	0.1
LFS	loamy fine sand	25	0.35	0.25	0.1	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
LFS		38		0.2	0.1	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
LFS		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.1	0.1	0.1
LFS		75		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.1	0.1	0.1	0.1	0.1
LS	loamy sand	25	0.35	0.25	0.1	0.175	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
LS		38		0.2	0.1	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
LS		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.1	0.1	0.1
LS		75		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.1	0.1	0.1	0.1	0.1
O	organic	50	0.5	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
O		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1
O		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
O		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
S	sand	25	0.4	0.25	0.1	0.175	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.1	0.15	0.2	0.1	0.15
S		38		0.2	0.1	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
S		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.15	0.1	0.125
SCL	sandy clay loam	38	0.15	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.15	0.1	0.125
SCL		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
SCL		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SCL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SI	silt	38	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SI		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.1	0.1	0.1
SI		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SI		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC	silty clay	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
SIC		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
SICL	silty clay loam	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
SICL		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SICL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075

SICL		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
SIL	silt loam	50	0.2	0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.1	0.05	0.075
SIL		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIL		125		0.1	0.05	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.075
SL	sandy loam	25	0.25	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
SL		38		0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SL		50		0.1	0.1	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.1	0.1	0.1
SL		75		0.1	0.1	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
VCSL	very coarse sandy loam	25	0.25	0.25	0.1	0.175	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.15	0.2	0.1	0.15
VCSL		38		0.2	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125
VCSL		50		0.15	0.1	0.125	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.125	0.15	0.1	0.125
VFSL	very fine sandy loam	38	0.25	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.1	0.15
VFSL		50		0.15	0.1	0.125	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.15	0.1	0.125
VFSL		75		0.15	0.1	0.125	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
VFSL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075

SoilId	Soil Class	MSWD	Infiltration Rate (mm)	SDI - poor	SDI - good	SDI - avg	Drip - poor	Drip - good	Drip - avg	Landscapesprinkler - poor	Landscapesprinkler - good	Landscapesprinkler - avg	Golfsprinkler - poor	Golfsprinkler - good	Golfsprinkler - avg	Subirrig - poor	Subirrig - good	Subirrig - avg
C	clay	50	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
C		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
C		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
C		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CL	clay loam	50	0.2	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
CL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
CL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CL		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CS	clayey sand	25	0.35	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
CS		38		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
CS		50		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CS		75		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
CSL	clayey sandy loam	25	0.25	0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
CSL		38		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
CSL		50		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
CSL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
default	default	25	0.25	0.2	0.1	0.15	0.2	0.1	0.15	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
default		38		0.15	0.1	0.125	0.15	0.1	0.125	0.25	0.1	0.175	0.25	0.1	0.175	0.25	0.1	0.175
default		50		0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15
default		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
FSL	fine sandy loam	38	0.25	0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
FSL		50		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
FSL		75		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
FSL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HC	heavy clay	50	0.1	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
HC		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
HC		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
HC		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
L	loam	38	0.2	0.15	0.05	0.1	0.15	0.05	0.1	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
L		50		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
L		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
L		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
LCS	loamy clayey sand	25	0.35	0.2	0.1	0.15	0.2	0.1	0.15	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
LCS		38		0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.25	0.15	0.2
LCS		50		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.2	0.15	0.175
LCS		75		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
LFS	loamy fine sand	25	0.35	0.2	0.1	0.15	0.2	0.1	0.15	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
LFS		38		0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.25	0.15	0.2
LFS		50		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.2	0.15	0.175
LFS		75		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
LS	loamy sand	25	0.35	0.2	0.1	0.15	0.2	0.1	0.15	0.3	0.25	0.275	0.3	0.25	0.275	0.3	0.25	0.275
LS		38		0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.25	0.15	0.2
LS		50		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.2	0.15	0.175
LS		75		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
O	organic	50	0.5	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
O		75		0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
O		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
O		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
S	sand	25	0.4	0.2	0.1	0.15	0.2	0.1	0.15	0.3	0.25	0.275	0.3	0.25	0.275	0.35	0.25	0.3
S		38		0.15	0.1	0.125	0.15	0.1	0.125	0.25	0.15	0.2	0.25	0.15	0.2	0.3	0.15	0.225
S		50		0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.25	0.15	0.2
SCL	sandy clay loam	38	0.15	0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
SCL		50		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SCL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SCL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SI	silt	38	0.2	0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
SI		50		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SI		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SI		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC	silty clay	50	0.2	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SIC		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SIC		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIC		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SICL	silty clay loam	50	0.2	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SICL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SICL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075

SICL		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIL	silt loam	50	0.2	0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SIL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1
SIL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SIL		125		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.05	0.075
SL	sandy loam	25	0.25	0.2	0.1	0.15	0.2	0.1	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
SL		38		0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
SL		50		0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
SL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
VCSL	very coarse sandy loam	25	0.25	0.2	0.1	0.15	0.2	0.1	0.15	0.3	0.25	0.275	0.3	0.25	0.275	0.35	0.25	0.3
VCSL		38		0.15	0.1	0.125	0.15	0.1	0.125	0.25	0.2	0.225	0.25	0.2	0.225	0.3	0.2	0.25
VCSL		50		0.15	0.1	0.125	0.15	0.1	0.125	0.2	0.15	0.175	0.2	0.15	0.175	0.25	0.15	0.2
VFSL	very fine sandy loam	38	0.25	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.15	0.175	0.2	0.15	0.175	0.2	0.15	0.175
VFSL		50		0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
VFSL		75		0.1	0.05	0.075	0.1	0.05	0.075	0.15	0.1	0.125	0.15	0.1	0.125	0.15	0.1	0.125
VFSL		100		0.1	0.05	0.075	0.1	0.05	0.075	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

SoilId	Soil Class	MSWD	Infiltration Rate (mm)	Flood - poor	Flood - good	Flood - avg
C	clay	50	0.1	0.3	0.3	0.3
C		75		0.3	0.3	0.3
C		100		0.25	0.25	0.25
C		125		0.25	0.25	0.25
CL	clay loam	50	0.2	0.3	0.3	0.3
CL		75		0.3	0.3	0.3
CL		100		0.25	0.25	0.25
CL		125		0.25	0.25	0.25
CS	clayey sand	25	0.35	0.3	0.3	0.3
CS		38		0.3	0.3	0.3
CS		50		0.25	0.25	0.25
CS		75		0.25	0.25	0.25
CSL	clayey sandy loam	25	0.25	0.35	0.35	0.35
CSL		38		0.3	0.3	0.3
CSL		50		0.25	0.25	0.25
CSL		75		0.2	0.2	0.2
default	default	25	0.25	0.4	0.4	0.4
default		38		0.35	0.35	0.35
default		50		0.3	0.3	0.3
default		75		0.25	0.25	0.25
FSL	fine sandy loam	38	0.25	0.35	0.35	0.35
FSL		50		0.3	0.3	0.3
FSL		75		0.25	0.25	0.25
FSL		100		0.2	0.2	0.2
HC	heavy clay	50	0.1	0.3	0.3	0.3
HC		75		0.3	0.3	0.3
HC		100		0.25	0.25	0.25
HC		125		0.25	0.25	0.25
L	loam	38	0.2	0.35	0.35	0.35
L		50		0.3	0.3	0.3
L		75		0.25	0.25	0.25
L		100		0.2	0.2	0.2
LCS	loamy clayey sand	25	0.35	0.4	0.4	0.4
LCS		38		0.35	0.35	0.35
LCS		50		0.3	0.3	0.3
LCS		75		0.25	0.25	0.25
LFS	loamy fine sand	25	0.35	0.4	0.4	0.4
LFS		38		0.35	0.35	0.35
LFS		50		0.3	0.3	0.3
LFS		75		0.25	0.25	0.25
LS	loamy sand	25	0.35	0.4	0.4	0.4
LS		38		0.35	0.35	0.35
LS		50		0.3	0.3	0.3
LS		75		0.25	0.25	0.25
O	organic	50	0.5	0.3	0.3	0.3
O		75		0.3	0.3	0.3
O		100		0.25	0.25	0.25
O		125		0.25	0.25	0.25
S	sand	25	0.4	0.5	0.5	0.5
S		38		0.45	0.45	0.45
S		50		0.4	0.4	0.4
SCL	sandy clay loam	38	0.15	0.35	0.35	0.35
SCL		50		0.3	0.3	0.3
SCL		75		0.25	0.25	0.25
SCL		100		0.2	0.2	0.2
SI	silt	38	0.2	0.35	0.35	0.35
SI		50		0.3	0.3	0.3
SI		75		0.25	0.25	0.25
SI		100		0.2	0.2	0.2
SIC	silty clay	50	0.2	0.3	0.3	0.3
SIC		75		0.3	0.3	0.3
SIC		100		0.25	0.25	0.25
SIC		125		0.25	0.25	0.25
SICL	silty clay loam	50	0.2	0.3	0.3	0.3
SICL		75		0.3	0.3	0.3
SICL		100		0.25	0.25	0.25

SICL		125		0.25	0.25	0.25
SIL	silt loam	50	0.2	0.3	0.3	0.3
SIL		75		0.3	0.3	0.3
SIL		100		0.25	0.25	0.25
SIL		125		0.25	0.25	0.25
SL	sandy loam	25	0.25	0.4	0.4	0.4
SL		38		0.35	0.35	0.35
SL		50		0.3	0.3	0.3
SL		75		0.25	0.25	0.25
VCSL	very coarse sandy loam	25	0.25	0.5	0.5	0.5
VCSL		38		0.45	0.45	0.45
VCSL		50		0.4	0.4	0.4
VFSL	very fine sandy loam	38	0.25	0.35	0.35	0.35
VFSL		50		0.3	0.3	0.3
VFSL		75		0.25	0.25	0.25
VFSL		100		0.2	0.2	0.2