NIWA
Taihoro Nukurangi

Peer review of current use of Gisborne District Council's irrigation water allocation model

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Executive summary

Gisborne District Council (GDC) has been applying a spreadsheet-based model developed by Aqualinc Research Limited to estimate irrigation water requirements for various crop types in the Poverty Bay Flats area. As the water requirement from this model has been perceived to be larger than what is likely used, the council allocates a portion of model-calculated irrigation water volumes. We reviewed the suitability and defensibility of these adjustments. This review and report were funded through Envirolink Small Advice Grant 2145-GSDC167.

A list of key recommendations based on the review of the spreadsheet model are given below.

1. Limiting allocation to (crop) growing season is valid. Allocations may further be refined if crop stage during growing season is considered. However, these limits should only be applied after careful consideration of changes in actual water use for a few irrigation seasons, for each crop type.

2. Irrigation water requirements vary with climate, and soil and crop types (e.g. dry /wet seasons, soil water holding capacity and rooting depth). While the daily and weekly irrigation requirements are held the same for all soil types for a given crop, the seasonal irrigation requirements are varied, though less substantially for non-permanent crops. It is not possible to confirm how water requirements calculated by the spreadsheet model consider these factors. The underpinning irrigation demand model (soil water balance model) needs to be reviewed to ensure that such variations are appropriately considered while assessing water requirements.

3. Absence of information on the geographical location of the farm in the spreadsheet model indicates that appropriate region-specific weather and water demand information may not be used in the irrigation water requirement calculations. This needs to be reviewed.

4. Calculation of irrigation water requirements is not explicitly linked to any specific irrigation scheduling approach. It is important that water allocation takes into account best irrigation practices (retention of most irrigation within the rootzone with little to no drainage or overland flow losses).

5. Preferably the irrigation water requirement calculation should consider the method of irrigation application that maximises irrigation efficiency and timing linked to climate (e.g. avoiding irrigation immediately before or after and during significant rainfall events), soil drainage characteristics (e.g. less intense irrigation on well-draining soils) and crop stage (e.g. limiting irrigation allocation during harvest season).

We also recommend that GDC review the underlying irrigation demand model to ensure the above recommendations are appropriately investigated and implemented. This includes collection and analysis of actual water use data for various crop types. We foresee that the implementation of above recommendations would significantly alter current water allocation process. This will also make the process defensible, in line with best management practices, and consistent with actual crop water needs.

1 Background and requirements

In 2012, Aqualinc Research Limited (Aqualinc) had developed a set of guidelines for the Gisborne District Council (GDC) to determine irrigation water requirements for various crops grown in the Poverty Bay Flats. In 2017, at the behest of GDC, Aqualinc updated the guidelines and developed a spreadsheet model (“model”) based on their (Aqualinc’s) in-house water demand model. While using the model over the past few years, GDC has developed a perception that the irrigation water requirements produced by the model do not necessarily reflect what would be expected for certain crop types. Consequently, GDC has been applying adjustments to better match expected irrigation water use requirements. Currently GDC has been allocating average water demand. To ensure that consistent and defensible good practices are followed in applying the model, GDC has requested NIWA to peer review the adjustments applied (by GDC) to the model and provide recommendations as necessary.

This review was funded through Envirolink Small Advice Grant 2145-GSDC167.

2 Scope and application of the advice sought

Water allocation is a key management issue in the Poverty Bay Flats area. Ensuring a robust process is followed in determining irrigation water allocation is fundamental to achieving good environmental outcomes. Advice was requested to improve the transparency and robustness of the water allocation process that would ensure a fair resource allocation and improved environmental outcomes. The advice will support GDC in decision-making when reviewing resource consent applications to take water for irrigation.

NIWA peer review considered the spreadsheet model and input data such as crop type, irrigated area, soil type, duration of irrigation season, and output generated by the model such as irrigation water requirements. NIWA considered if there was a need to include additional crops to the model. NIWA peer review did not examine the underpinning demand model.

3 Approach

Following the approval of this project, NIWA scientists held a video conference with Mr Paul Murphy and Ms Olive Steven from GDC. The purpose of the meeting was to:

1. Learn to use the (spreadsheet) model, which is for GDC internal use only and not available in the public domain; and

2. Learn how and what adjustments are applied by GDC to the model in arriving at an allocation number.

During that meeting, the GDC team walked the NIWA team through the model, including data entry (crop type, area, soil type, months of irrigation allocation requested) and output (average demand based on adjusted season and 1-in-10 year drought). GDC has been allocating a proportion of average annual volume estimated by the model. These adjustments were considered as a part of the review.

The model currently considers a wide variety of crop types: lettuce, baby leaf, broccoli, cabbage, onions, melons, squash-A and B, tomatoes, citrus, kiwifruit, sweet corn, maize, pasture, apple, persimmons, and feijoas.

Based on the information gathered from the GDC team on the model and subsequent testing of the model, NIWA has come up with a suite of recommendations that are listed in the next section.

During the review process, NIWA team extensively consulted Environment Canterbury's (ECan) Canterbury Land and Water Regional Plan Volume 1 (ECan 2018), as this plan was developed with significant input from a range of primary sector and industry groups. In this report, we have identified appropriate tables and schedules from the above regional plan that were used in our review and recommendations.

4 Recommendations

1. The adjustment of irrigation allocation to match the growing season of different crop types is appropriate. The irrigation allocation for non-growing season should be zero. This has also been advocated in other regional plans such as Canterbury Land and Water Regional Plan Volume 1 (ECan 2018).

   Further adjustments to irrigation allocation during the growing season could be considered in the future. Irrigation demand varies during growing season, with most irrigation demand occurring during early and establishment stages (particularly for vegetables), and the least towards harvest. While the spreadsheet model includes growing season for a selection of crop types, it is not clear if the irrigation demands are varied within growing season.

   It might also be useful to refer to Schedule 28 (page 559), and specifically Table s28, *Good management practices and modelling rules applied by the farm portal* (page 560), of Canterbury Land and Water Regional Plan Volume 1 (ECan 2018). The topic *"Irrigation and water use"* provides guidance on when irrigation is not allowed during a growing season. This may provide additional justification for GDC to ground their adjustments.

2. While we did not look into the science of the underpinning irrigation demand model, we considered the allocation volumes (model output). The model outputs two different allocation volumes: (1) average demand, and (2) 1-in-10 year demand. Many regional councils allocate water based on 1-in-10 year demand, so it is valid to consider the same here. However, the calculation of water requirements for 1-in-10 demand needs further investigation which is discussed later in the review.

3. Based on the State of the Environment report (GDC 2021), a few more crop types could be included (if irrigated) to the water allocation model: avocado, tamarillo, persimmon, grapes and pear. Very likely some of the suggested crop types are similar to the ones already included in the model but it will be useful to explicitly identify them.

We also considered other aspects of the model and have identified a set of suggestions which we believe will assist with the allocation process. We believe these suggestions could potentially alter the allocation volumes and contribute to the environmental outcomes identified by GDC. The suggestions highlight the need to consider climate, soil drainage characteristics, topography, crop stage, and irrigation scheduling and application methods. In regions where the groundwater table could raise close to the surface and where subsurface drainage is widely practised, the irrigation water requirements could be low especially in winter and shoulder seasons. It is important that GDC collects sufficient field evidence on water use to ensure allocations are fair and justified.

- The methods used to calculate both annual demand volumes (average and 1-in-10 year drought demand) need additional clarification. The model lists the monthly values, which we assumed were calculated from daily outputs of the underlying irrigation demand model. The spreadsheet model adds up the monthly average and 1-in-10 year demand values for 12 months and presents them as annual values. The monthly values of 1-in-10 year demand values do not represent the continuous demand as these 1-in-10 year demand for different months can occur in different years. For example, January 1-in-10 year demand hypothetically can occur in 2010 and February 1-in-10 year demand in 2011. The procedure of adding monthly 1-in-10 year demand values to determine the annual demand could lead to a higher demand volume than what is needed in a 1-in-10 year drought. A more accurate and recommended method to calculate 1-in-10 year annual/seasonal demand is to calculate annual/seasonal demand for each year based on daily irrigation demand model, and then calculate the 1-in-10 year drought demand (90 percentile) using the annual/seasonal timeseries. It is also important that the annual/seasonal demands are calculated using water (or hydrological) years – from July to June. Use of monthly values from January to December will result in using demand from two different water years. Generally, irrigation season extends from September to April.

- The spreadsheet model consists of a tab listing daily, weekly and seasonal irrigation water requirements for various crop types (see, "Daily, weekly & seasonal demand" tab in the model; tables included as Appendix A). For a few crop types, the daily and weekly requirements are assumed to be the same irrespective of soil type and maximum rooting depth (see "Crop Details" tab in the model for maximum rooting depth; tables included as Appendix B). However, for vegetables, the rooting depth is shallow and leaf area is small during the early stage of development and increases as the crop grows. It is therefore not valid to assume same irrigation requirements throughout the growing season. Higher irrigation depths, particularly during the early stages, would result in poor use by crop, increasing the propensity of irrigation-drainage below the assumed soil water reservoir (this is referred as 'maximum rooting depth' in the model; Appendix B). The general practice while irrigating vegetable crops is to vary the application depth and design the return period of irrigation events based on crop stage; small and regular application of irrigation at early stages when roots are shallow and gradually increasing the application depth as the roots get deeper. The Waikato Regional Council's irrigation guidelines has adopted this type of variable irrigation management practice (Rajanayaka et al. 2016).

- Even though the rooting depth of broccoli, onion and tomato varied significantly (from 25 to 100 cm; see Appendix B), the daily and weekly irrigation water requirements are maintained the same for all three, and for all soil types. Justification for not varying irrigation water requirements with soil type and crop type is needed.

- If the irrigation water requirements used in the model (Appendix A) represent evaporative losses, then it needs to be justified why the daily irrigation water requirement numbers are maintained the same throughout the year, and for all crop types that widely vary in their water use. Generally, evaporative losses vary between seasons and within a season. For example, Van Housen (2015), based on a field study in North Canterbury, reported that evaporative losses for pasture vary significantly within irrigation season. This aspect of the model needs to be reviewed to accommodate variations in evaporative losses (preferably at no more than monthly scale).

- If the recommendation of altering irrigation demand to match crop stages (establishment versus harvest stage, for example, as discussed above) is to be pursued, then it would require GDC to change irrigation allocations dynamically instead of allocating same volume throughout the season. To enable a dynamic allocation, GDC needs to collect data on actual water use (preferably daily) to understand the changes (in water use) over the growing season for each crop type (except pasture). When comparing actual water use, the underlying irrigation demand model needs to be run using the weather data from same season as the actual water use data. The actual water use data should not be compared against average or 1-in-10 year allocation.

- In the absence of any information on how irrigation demands are calculated in the model, we are unable to confirm the validity of demand calculations. It is not obvious how rainfall and evapotranspiration information are included in the model to estimate demand. We recommend that the underlying demand model is reviewed to check the validity of demand calculations. The model input does not include spatial location of farms considered, which means no site-specific weather information is used in the demand calculation. This needs to be reviewed and the model updated accordingly.

- It is not clear how the model links irrigation water requirements (Appendix A) to irrigation methods, soil type and (maximum) rooting depth for each crop type (Appendix B). The daily and weekly water requirements are maintained the same but the seasonal water requirements vary between soils types. It is not obvious how the water requirements are varied over a season. Also, the seasonal water requirements for non-permanent crops did not appear to differ significantly between soil types. This needs to be reviewed.

- Information on irrigation methods used for each crop type is included in the model (see Appendix B). However, it is not clear if these are the suggested methods or the dominant ones in the Poverty Bay Flats area. How are these methods used in demand calculation? Do resource consent applications require the irrigation method, application efficiency and scheduling practice to be identified? It will be useful to consider the guidance provided in ECan (2018) on irrigation application on various soil types (see, *Method s28.4: Methodology for the application of irrigation water by spray irrigation systems under Good Management Practice, page 570*). GDC may want to include the use of irrigation method and scheduling practice in their allocation process.

- In Canterbury, where the majority of country's irrigation occur, the regional council mandates an irrigation application efficiency of 80% (ECan 2018). GDC should consider this as a part of their resource consenting process and the irrigation allocation needs to include an 80% irrigation application efficiency. Irrigation application efficiency means the volume of water stored in the plant-soil water reservoir (root) zone following irrigation, as a percentage of the total volume applied. The irrigation water requirement calculation should include an application efficiency factor. There is also a need to have option for the water users to provide evidence for irrigation application efficiency. Outputs such as the one shown in Appendix C have been used by some Canterbury farmers as an evidence of good irrigation practice. Farm Environment Plan (FEP) auditors in Canterbury consider such evidence as valid and more than sufficient (pers. comm. Wren, M., FEP auditor, Canterbury).

- Schedule 7 Farm Environment Plan (*5B Management Area: Irrigation; Page 435*) of Canterbury Land and Water Regional Plan Volume 1 (ECan 2018) requires that the timing and depth of irrigation water applied should take account of crop requirements and justified through soil moisture monitoring or soil water budgets, and climate information. The model used by GDC does not include depth of water applied per irrigation event or timing of irrigation applied. It includes daily and weekly water requirements but does not have the option of including how irrigation events are scheduled and how much is applied per event. Without this information, it is difficult to project the likely irrigation use efficiency used in the underlying demand model. In some soil types, the assumed irrigation application methods (e.g., guns or travelling irrigators on well-draining soils) may need to be reviewed. The GDC model does not appear to consider irrigation application efficiency (or explicitly identified as an input to the model). GDC may want to ensure that appropriate irrigation application depths and return intervals are used for efficient water use as a part of the allocation process.

- The Canterbury Land and Water Regional Plan Volume 1 (ECan 2018) mandates the inclusion of soil drainage characteristics and topography of land irrigated in managing irrigation. The model developed by Aqualinc does not include either one of them. However, we believe that topography might be of less concern to Poverty Bay Flats area. Soil drainage might be considered using outputs such as those shown in Appendix C.

- The recent report from the Ministries for the Environment and Primary Industries (2021) on Overseer model indicates that the government is developing best practice guidelines for models used for environmental regulations The guidelines will insist on transparency, and description of scientific principles applied and sources of data used. The government also demands that such models should be available for public review (page 8, Ministry for the Environment and Ministry for Primary Industries, 2021). It is important for GDC to ensure that the spreadsheet model and underpinning irrigation demand model are peer-reviewed and become available for public review in line with government guidance.

5 Acknowledgements

This project was funded by a MBIE Envirolink advice grant 2145-GSDC167.

We thank the GDC staff, Dr Murry Cave, Mr Paul Murphy and Ms Olive Steven for their input to the review process.

6 Glossary of abbreviations and terms

ECan	Environment Canterbury
GDC	Gisborne District Council
NIWA	National Institute of Water and Atmospheric Research Limited

7 References

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Rajanayaka, C., Brown, P., Jaramillo, A. (2016) Guidelines for Reasonable Irrigation Water Requirements in the Waikato Region Waikato Regional Council, H12002803. Aqualinc Research Limited. 109 pages.

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Appendix A Irrigation water requirement

Daily, monthly and seasonal irrigation water requirements for various crop listed in the spreadsheet model (tab, “Daily, weekly & seasonal demand”).

Daily irrigation water requirement

Soil group	daily irrigation water requirement (mm/day)															
	Lettuce	Baby Leaf	Broccoli	Cabbage	Onions	Melons	Squash-A	Squash-B	Tomatoes	Citrus	Kiwifruit	Sweet corn	Maize	Pasture	Apple	Persimmons	Feijoas
A	4.0	4.0			4.0												
B	4.0	4.0	4.0	4.0	4.0												
C	4.0	4.0	4.0	4.0	4.0												
D	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0			5.0			5.0			
E	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.8			5.0			4.0
F	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.7	5.0	5.0	5.0			4.0
G	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.6	5.0	5.0	5.0			4.0
H	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.5	5.0	5.0	5.0	4.3	4.3	3.9
NC	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.8	4.2	5.0	5.0	5.0	4.1	4.1	3.8

Weekly irrigation water requirement

Soil group	weekly irrigation water requirement (mm/week)															
	Lettuce	Baby Leaf	Broccoli	Cabbage	Onions	Melons	Squash		Tomatoes	Cirtus	Kiwifruit	Sweet corn	Maize	Pasture	Apple	Persimmons	Feijoas
A	28	28	-	-	28	-	-	-	-	-	-	-	-	-	-	-	-
B	28	28	28	28	28	-	-	-	-	-	-	-	-	-	-	-	-
C	28	28	28	28	28	-	-	-	-	-	-	-	-	-	-	-	-
D	28	28	28	28	28	28	28	28	-	-	35	-	-	35	-	-	-
E	28	28	28	28	28	28	28	28	28	28	34	-	-	35	-	-	28
F	28	28	28	28	28	28	28	28	28	28	33	35	35	35	-	-	28
G	28	28	28	28	28	28	28	28	28	28	32	35	35	35	-	-	28
H	28	28	28	28	28	28	28	28	28	27	32	35	35	35	30	30	27
NC	28	28	28	28	28	28	28	28	28	27	29	35	35	35	29	29	27

	1 in 10 year drought seasonal irrigation water requirement								
	Soil group								
	A 90 centile	**B 90 centile**	**C 90 centile**	**D 90 centile**	**E 90 centile**	**F 90 centile**	**G 90 centile**	**H 90 centile**	**NC 90 centile**
Lettuce	660	682	694	670	674	674	674	684	690
Baby Leaf	749	760	793	763	776	776	785	785	782
Broccoli		679	678	689	712	712	715	715	729
Cabbage		778	742	746	751	751	762	777	777
Onions	594	602	605	594	596	596	601	601	593
Melons				542	546	546	575	575	582
Squash-A				439	442	442	454	452	454
Squash-B				610	610	610	622	622	629
Tomatoes					654	659	681	689	710
Citrus					456	444	391	385	353
Kiwifruit				585	562	546	528	521	502
Sweet corn						325	354	360	369
Maize						332	338	346	353
Pasture				800	775	775	770	756	721
Apple								550	513
Persimmons								550	513
Feijoas					456	444	391	385	353

Appendix B Crop type, duration of growing season, irrigation methods and maximum rooting depth

Crop type, duration of growing season, irrigation methods and maximum rooting depth used in GDC's spreadsheet model.

Typical vegetable

Crops	Season	Irrigation methods	Maximum rooting depth (cm)
Lettuce	Grown all year round	Sprinkler Trickle	35
Baby Leaf	Grown all year round	Trickle	25
Broccoli	Grown all year round	Travelling boom/ Big Gun	50
Onions	July to February	Travelling boom/ Big Gun	25
Melons	September to April	Trickle	60
Squash A	August to January	Trickle	60
Squash B	August to April	Travelling boom/ Big Gun	60
Tomatoes	September to April	Travelling boom/ Big Gun	100

Typical irrigation

Crops	Season	Irrigation methods	Maximum rooting depth (cm)
Citrus	Year round	Drippers, mini sprinklers	70
Kiwifruit	November to April	Drippers, mini sprinklers	70
Sweet corn	October to January	Travelling boom	100
Maize	October to January	Travelling boom	80
Pasture	September to April	Centre-pivot, Lateral booms, K Lines	70
Apple	Year round	Drippers, mini sprinklers	100
Persimmons	Year round	Drippers, mini sprinklers	100
Feijoas	Year round	Drippers, mini sprinklers	70

Appendix C Insight soil moisture plot

The plot below is a product of NIWA's Irrigation Insight MBIE Endeavour programme. By measuring soil moisture within and below the root zone, the plot presents a near real-time information on soil water conditions within and below crop water reservoir. The inclusion of weather forecast allows an informed irrigation decision, reducing instances of unnecessary irrigation events.